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

Kirk R. Smith
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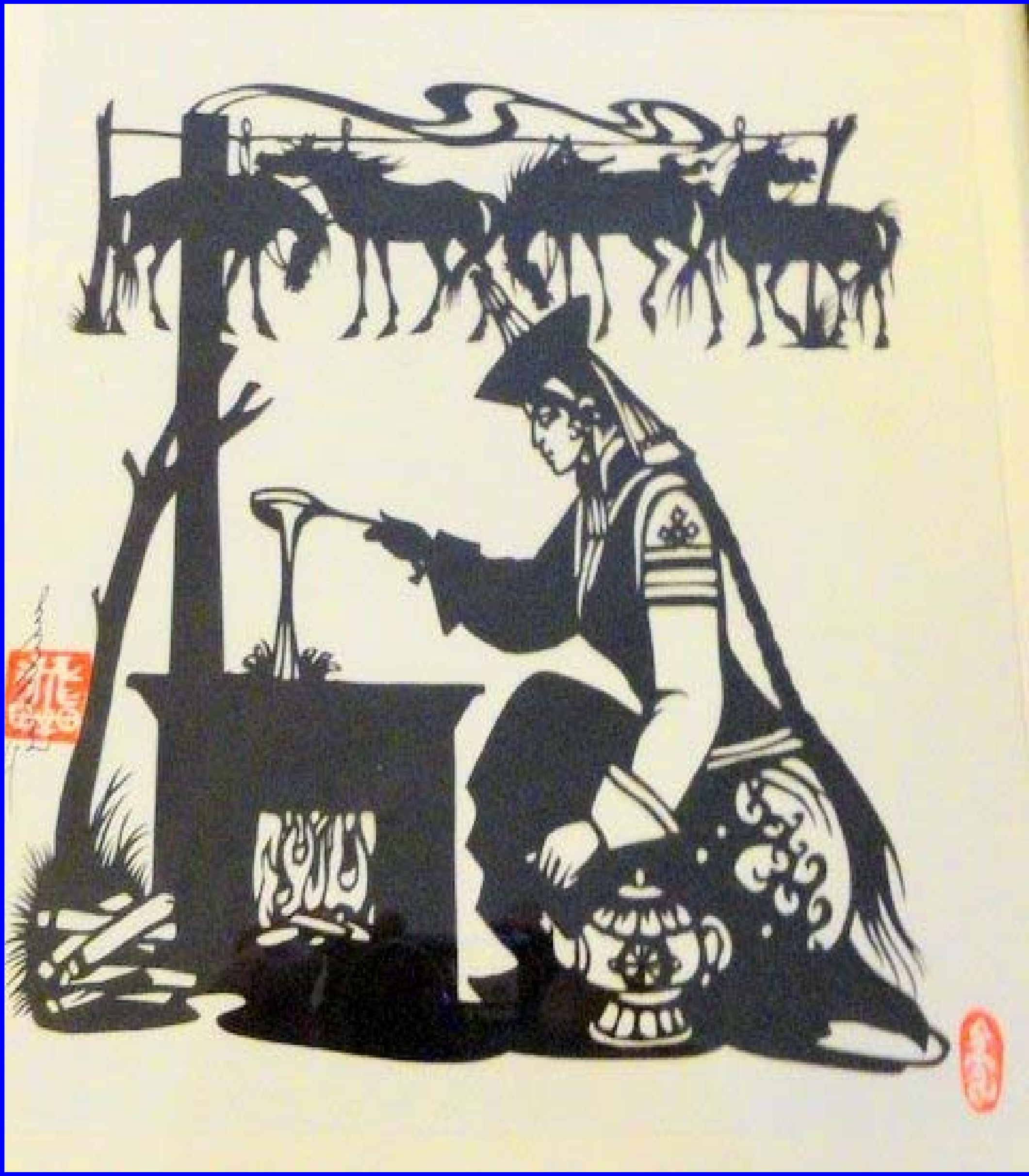
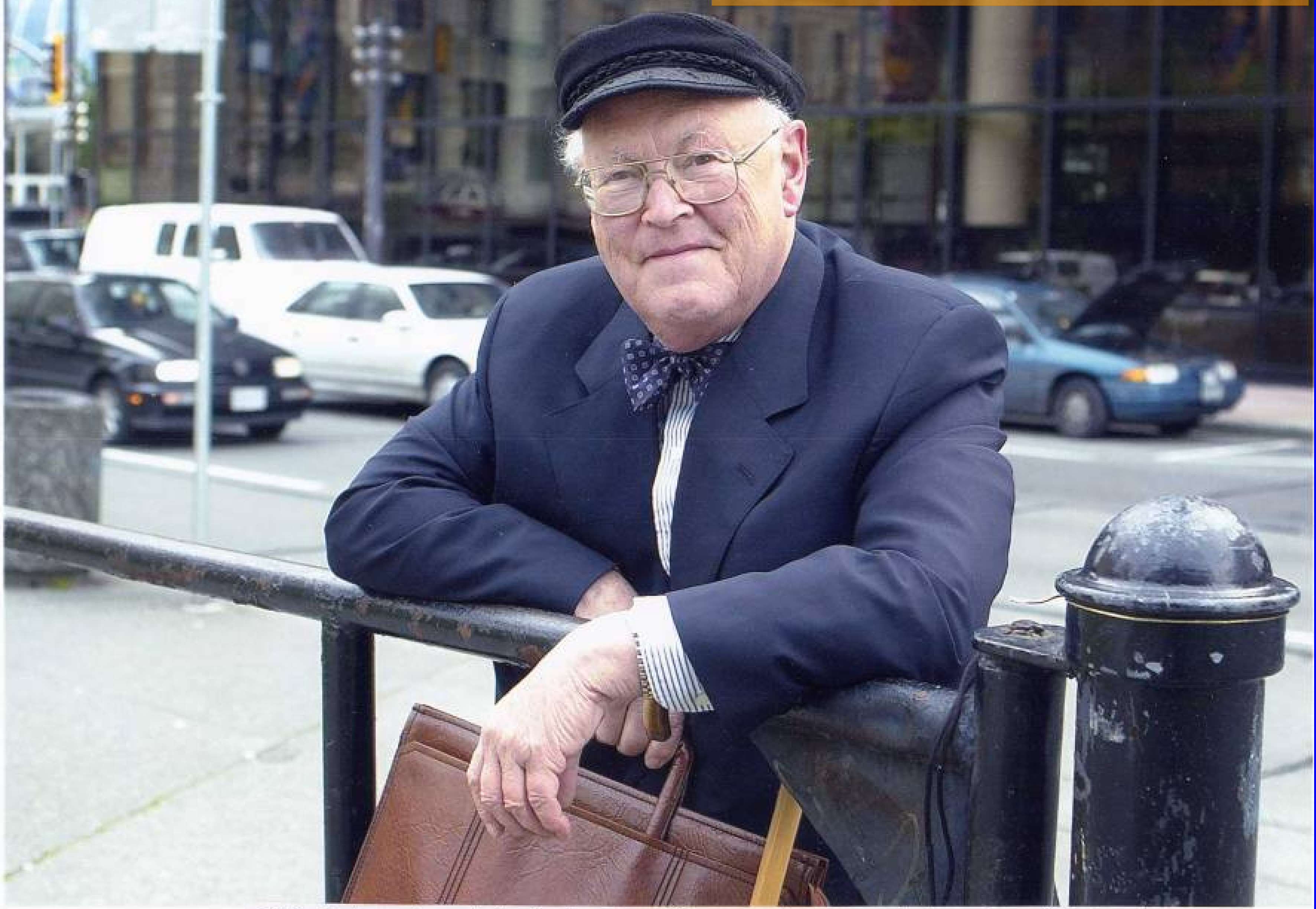
University of California, Berkeley

David Bates Memorial Lecture
Annual Symposium on Environmental, Occupational, and Population Health
Semiahmoo, Washington
Jan 6, 2012

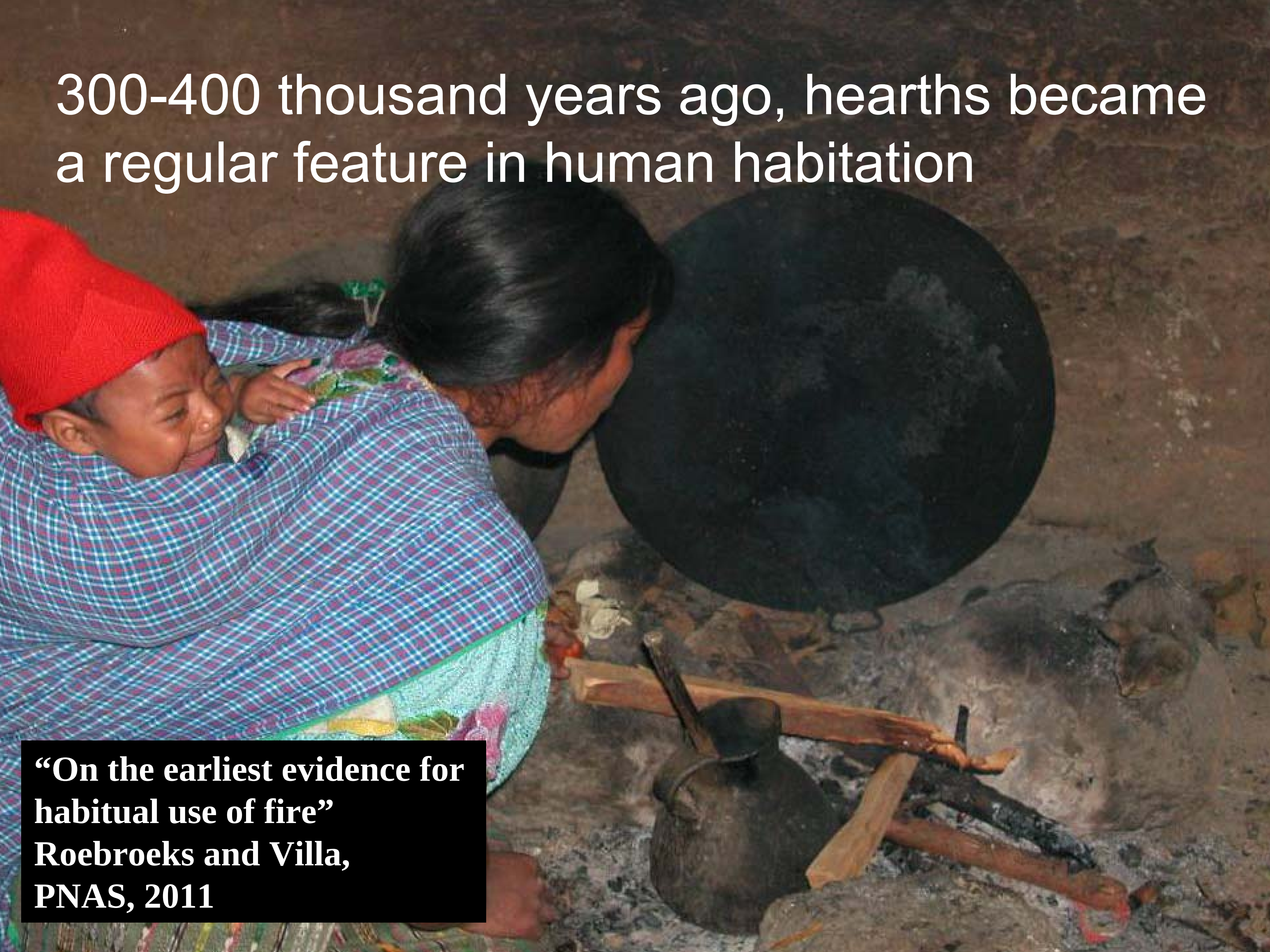


David V Bates 1922 - 2006



This photograph was taken in downtown Vancouver by a press photographer a few days before my 79th birthday in May 2001; it appeared on the front page of the Vancouver Sun on Saturday, May 19th 2001.

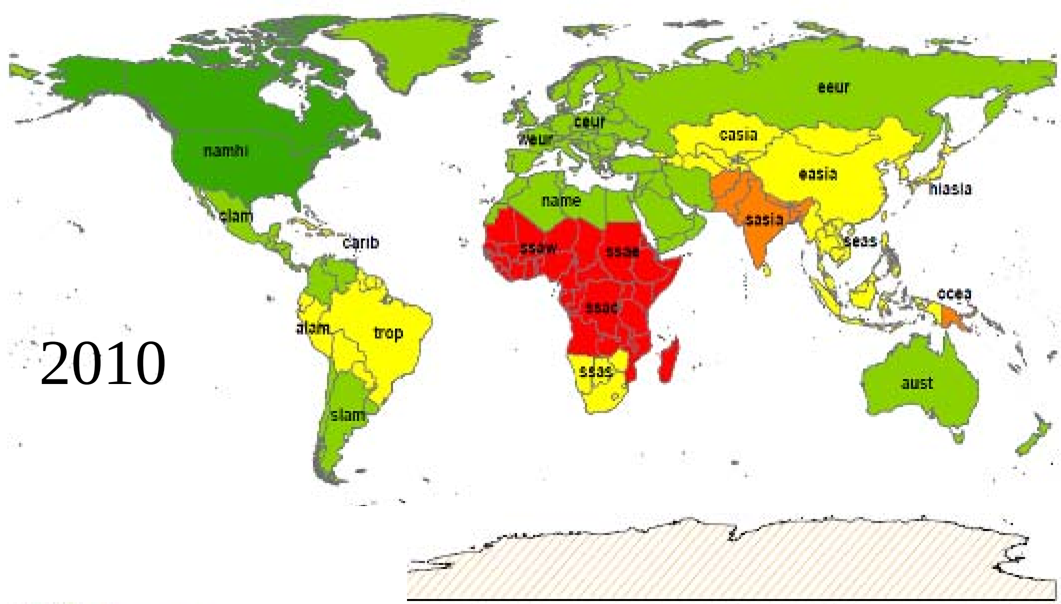
300-400 thousand years ago, hearths became a regular feature in human habitation



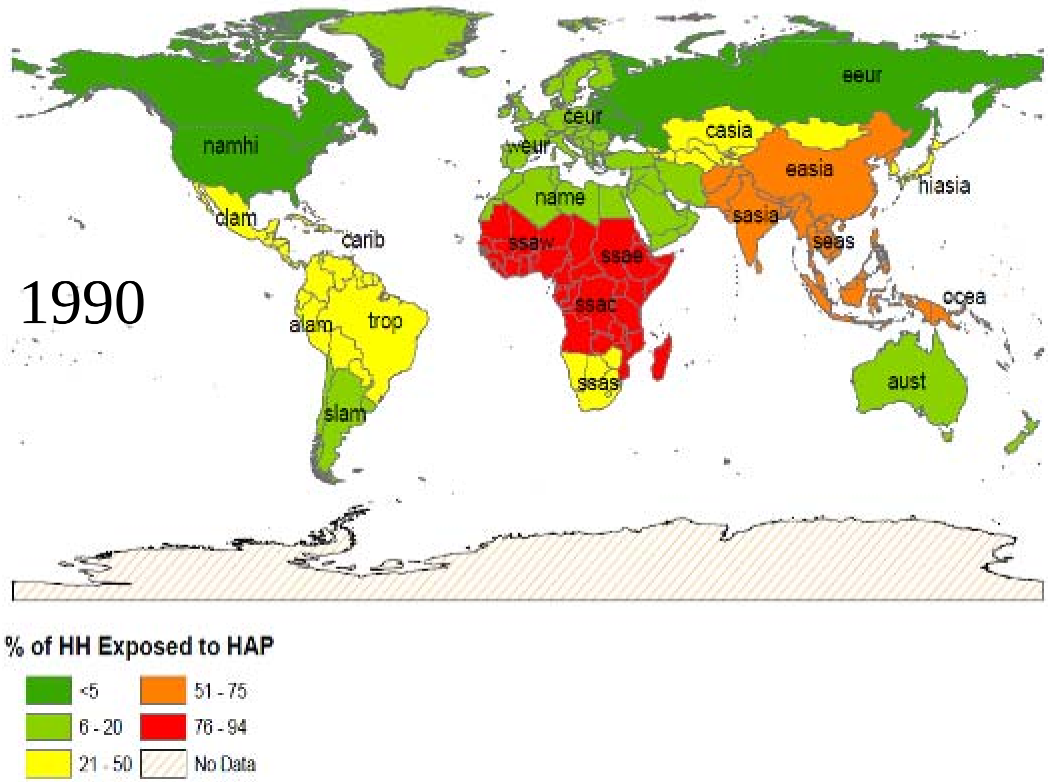
“On the earliest evidence for habitual use of fire”
Roebroeks and Villa, PNAS, 2011

Households using biomass or coal to cook

2010

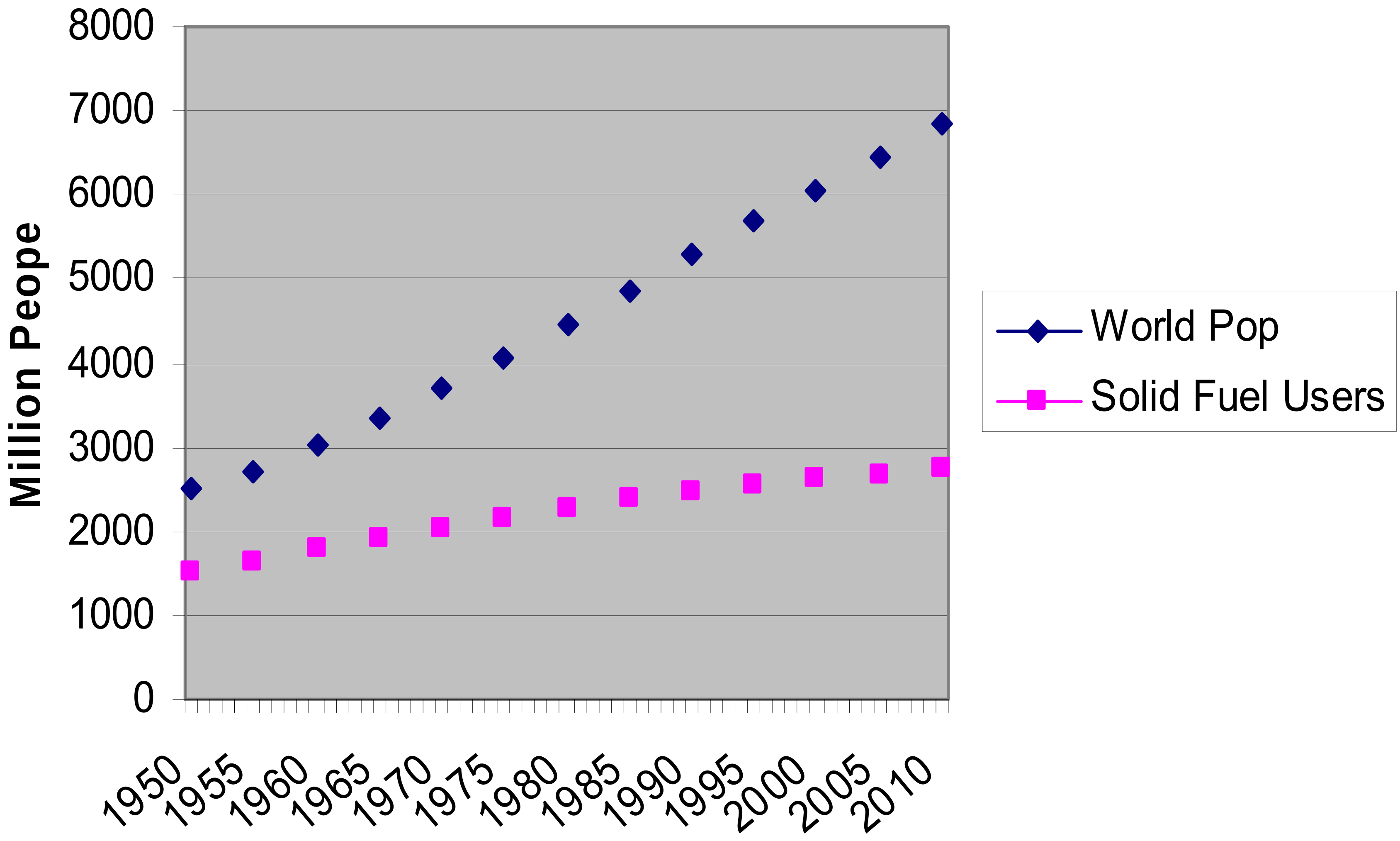


1990



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

World Population Using Solid Fuels




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

Into Pot	In PIC	Waste Heat
2.8 MJ	1.2 MJ	11.3 MJ
18%	8%	74%

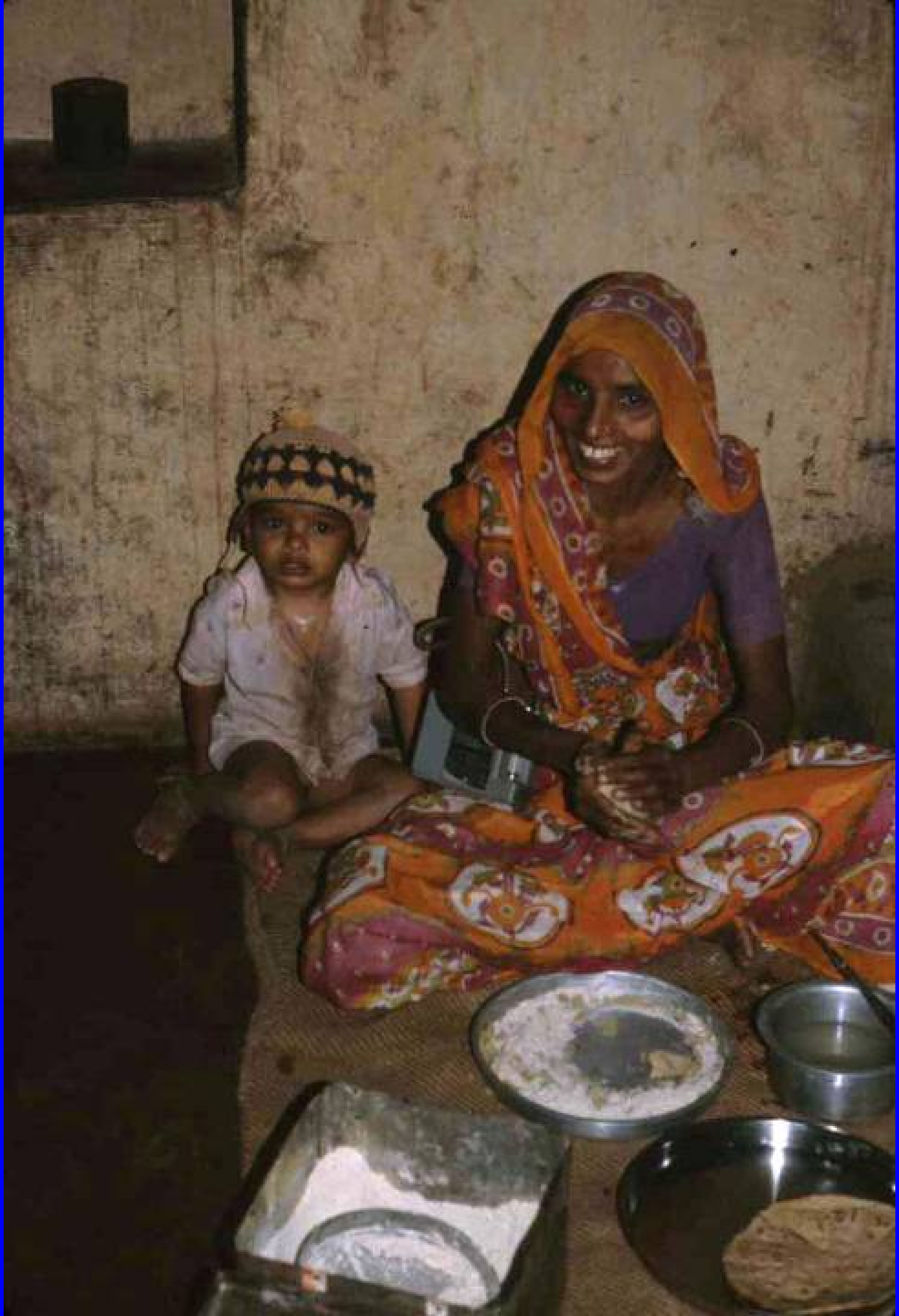
PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000

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

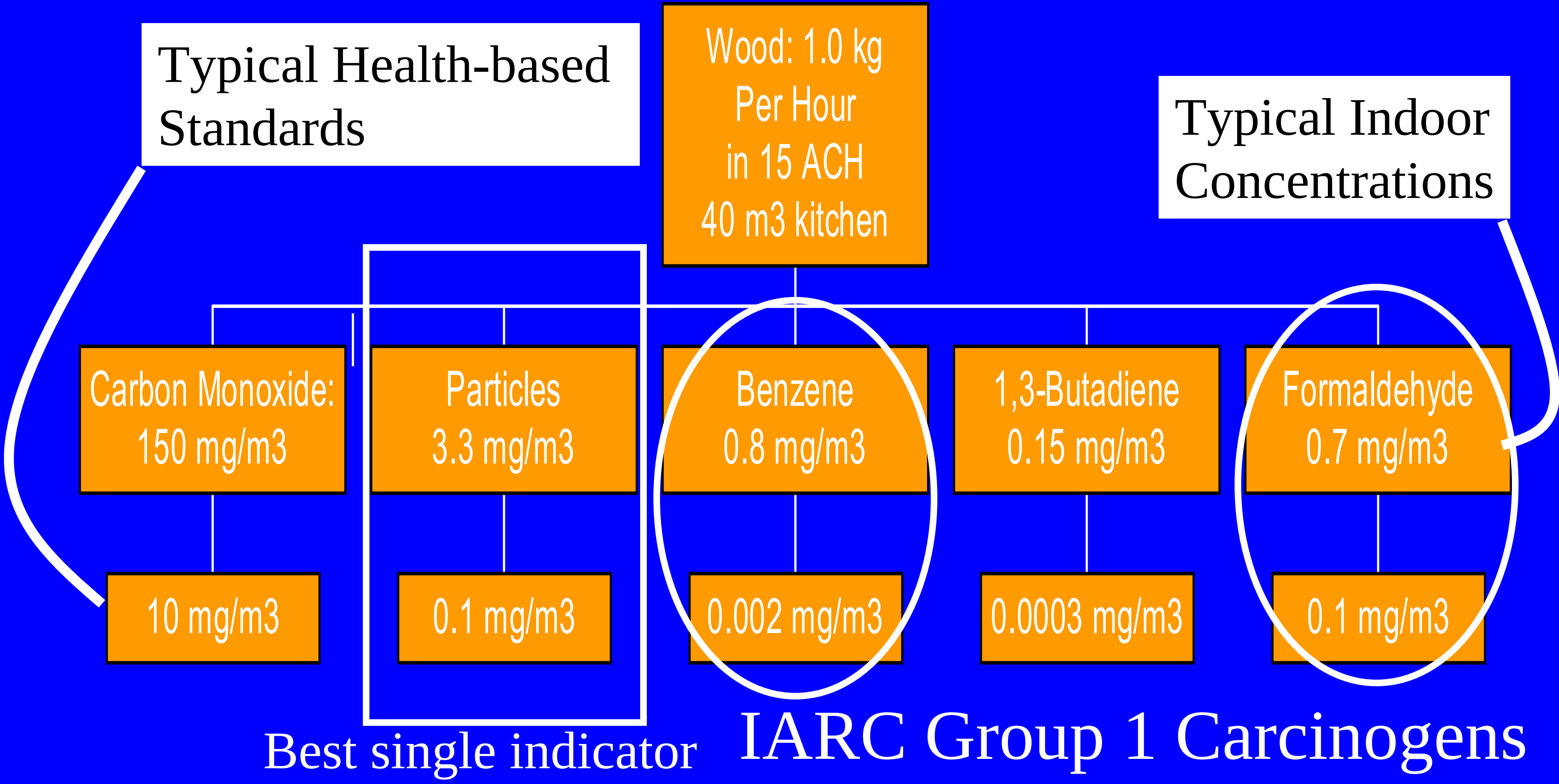
- Small particles, CO, NO_2
- Hydrocarbons
  - 25+ saturated hydrocarbons such as *n-hexane*
  - 40+ unsaturated hydrocarbons such as *1,3 butadiene*
  - 28+ mono-aromatics such as *benzene & styrene*
  - 20+ polycyclic aromatics such as *benzo(α)pyrene*
- Oxygenated organics
  - 20+ aldehydes including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

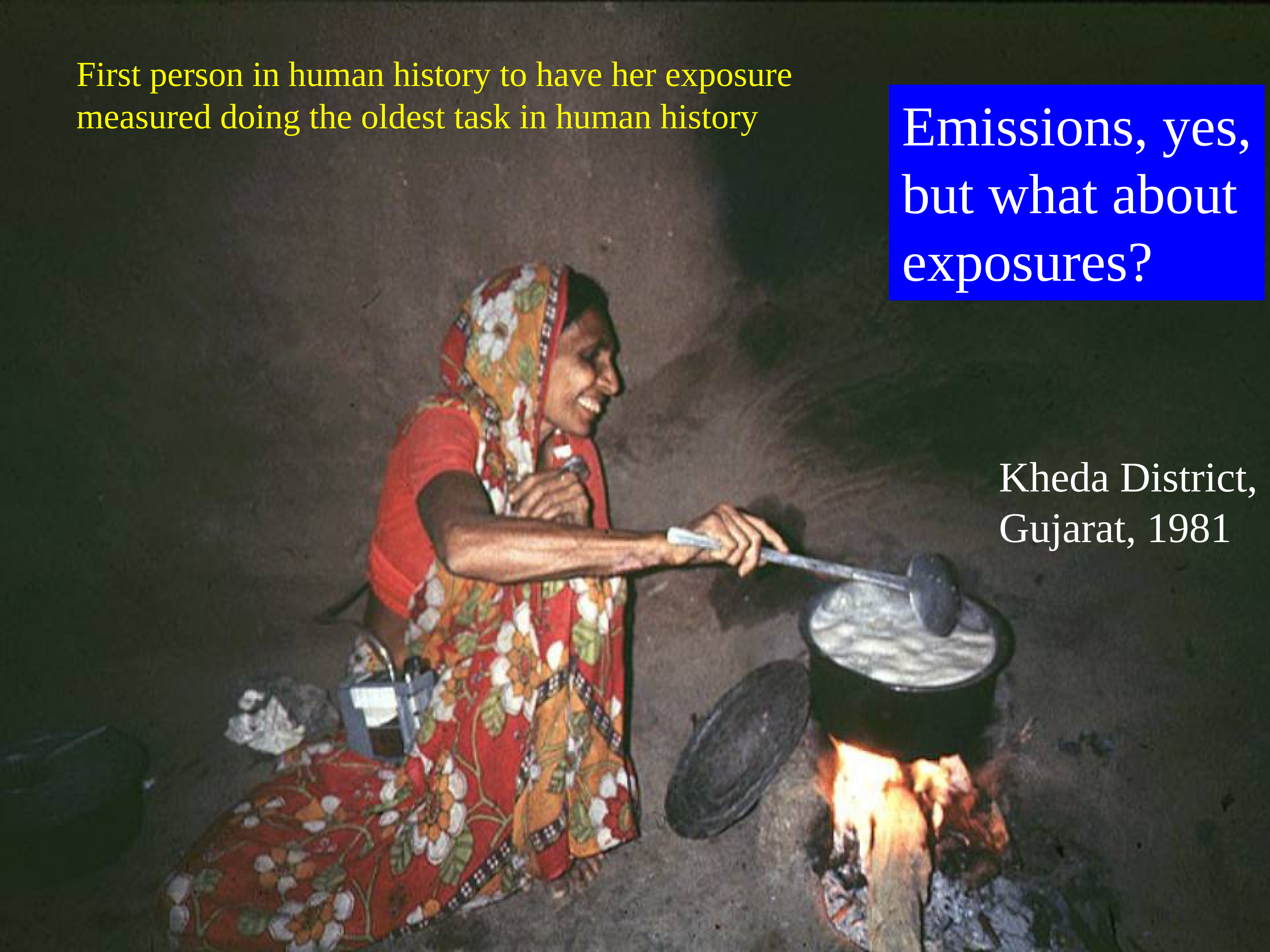
Source: Naeher et al, *J Inhal Tox*, 2007



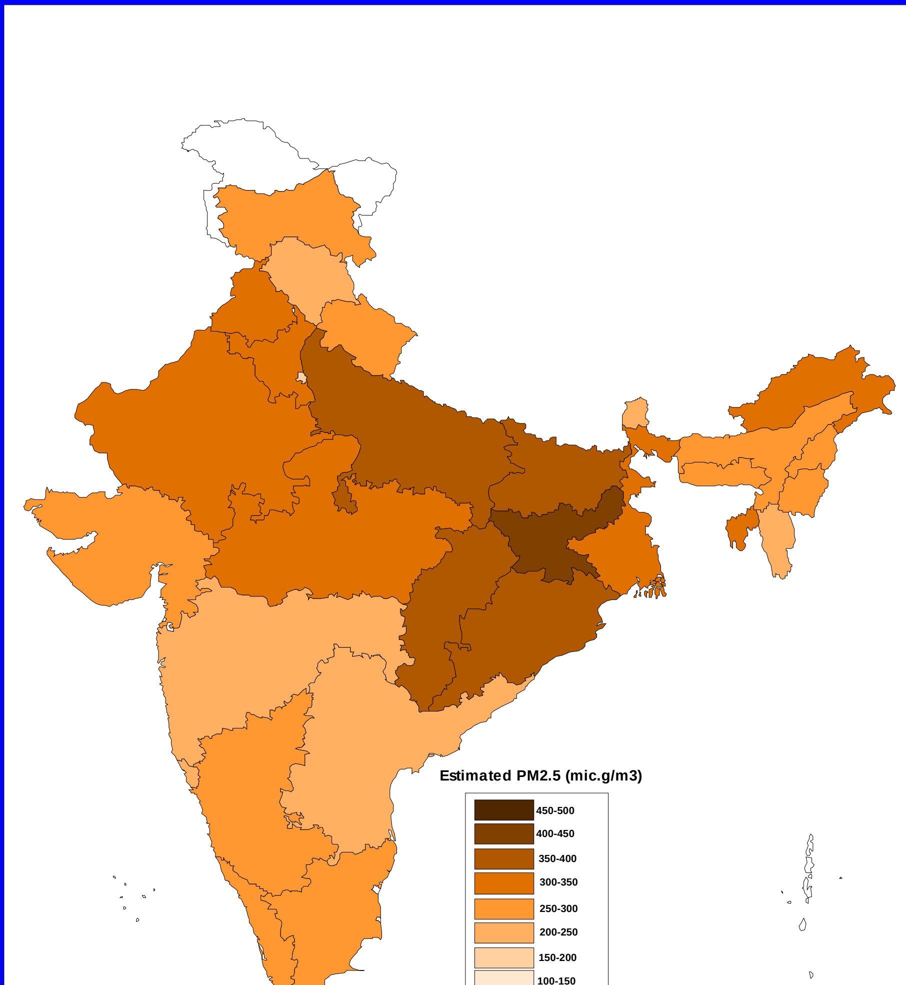
How much
Ill-health?

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



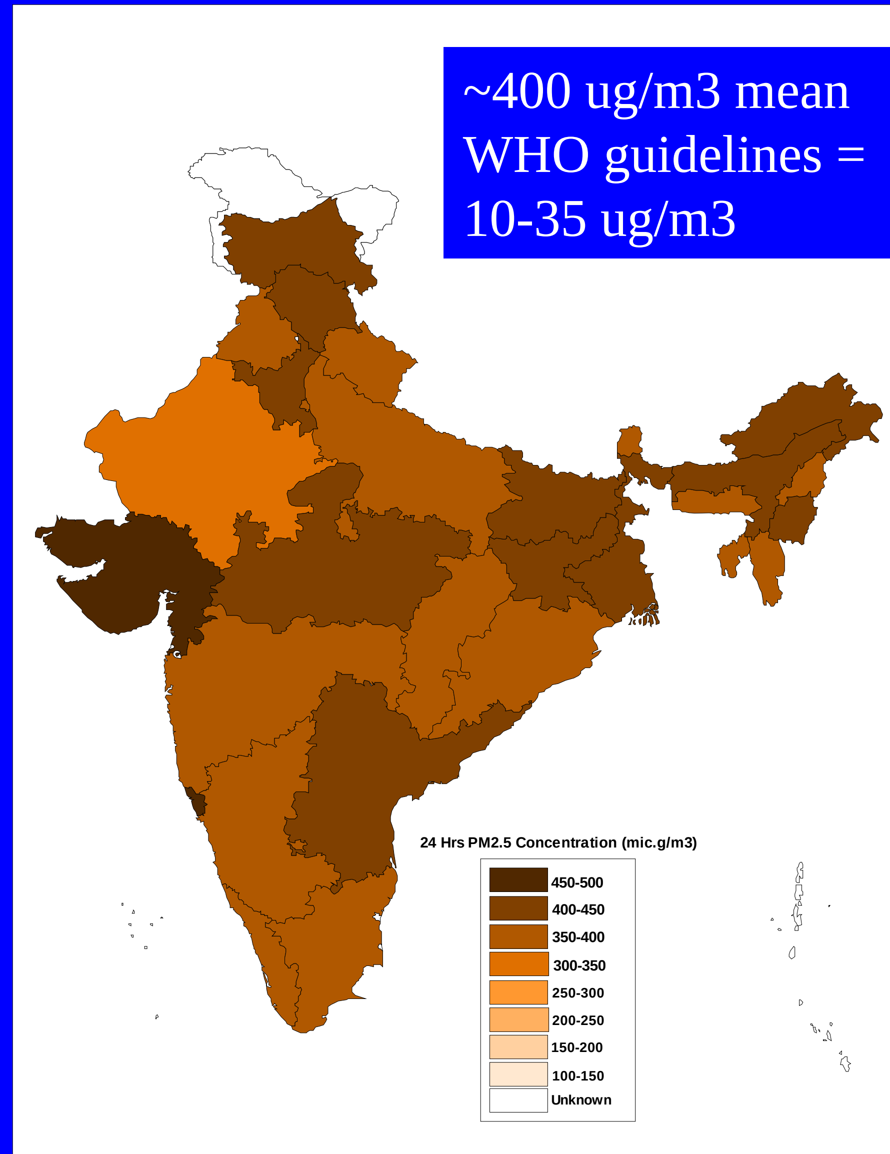

First person in human history to have her exposure measured doing the oldest task in human history
Emissions, yes, but what about exposures?
Kheda District, Gujarat, 1981

Estimated PM2.5 indoors for all households



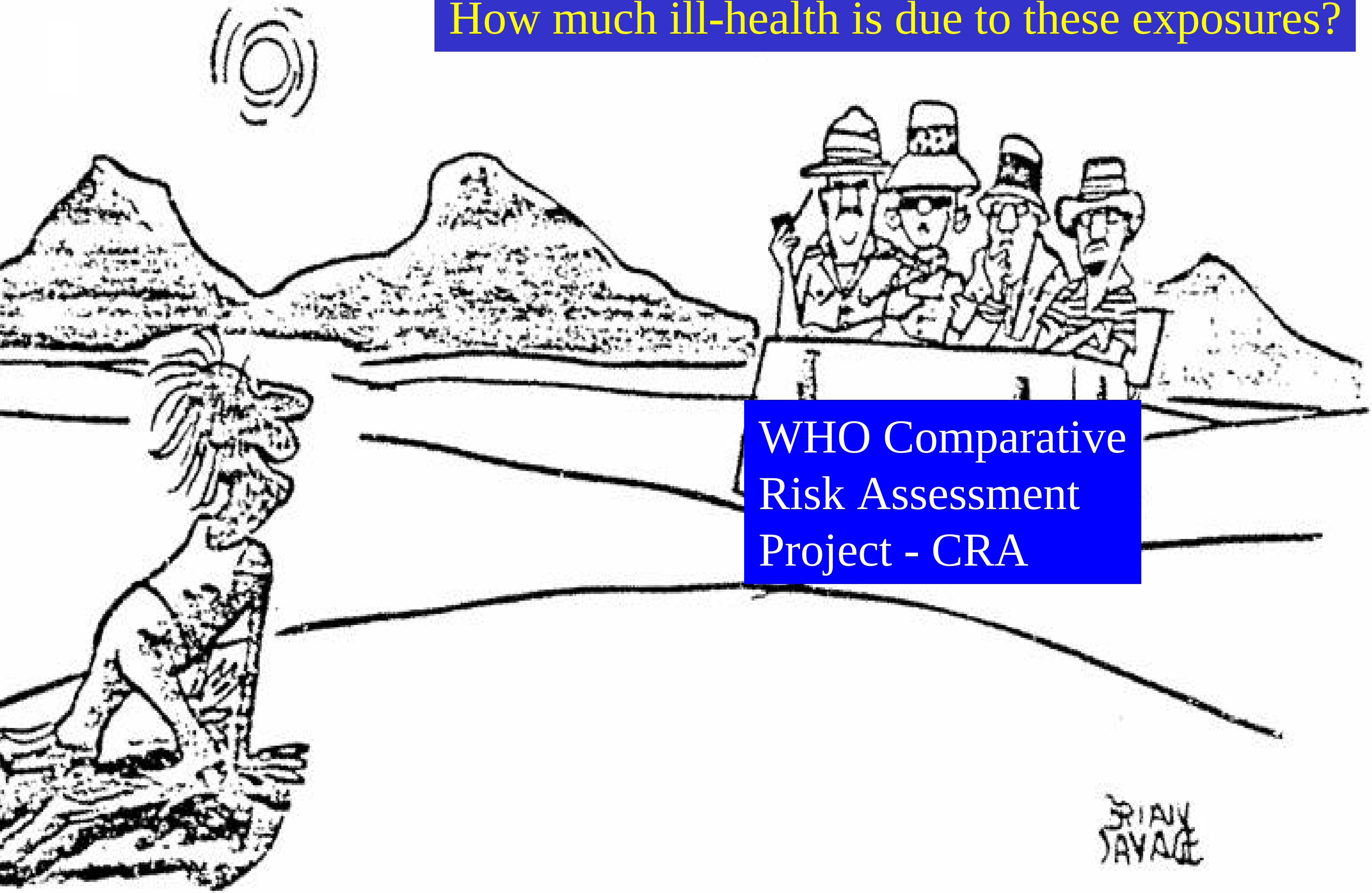
Estimated PM2.5 for only solid-fuel-using households

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



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

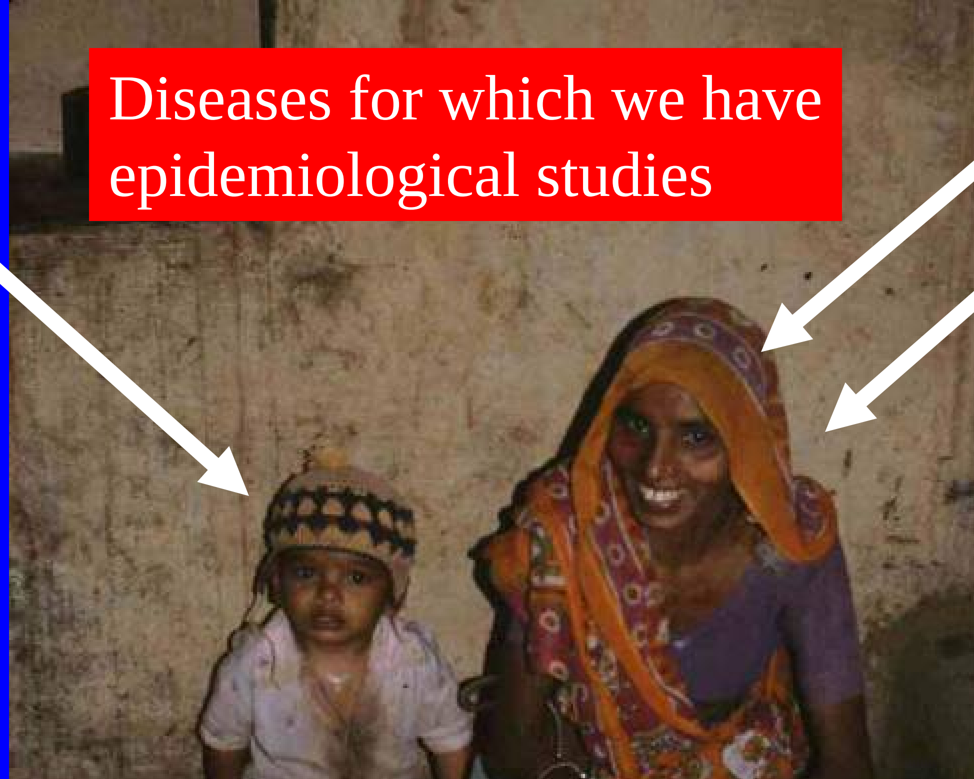
How much ill-health is due to these exposures?



"Thank God! A panel of experts!"

Courtesy of Ross Anderson

ALRI/
Pneumonia



COPD

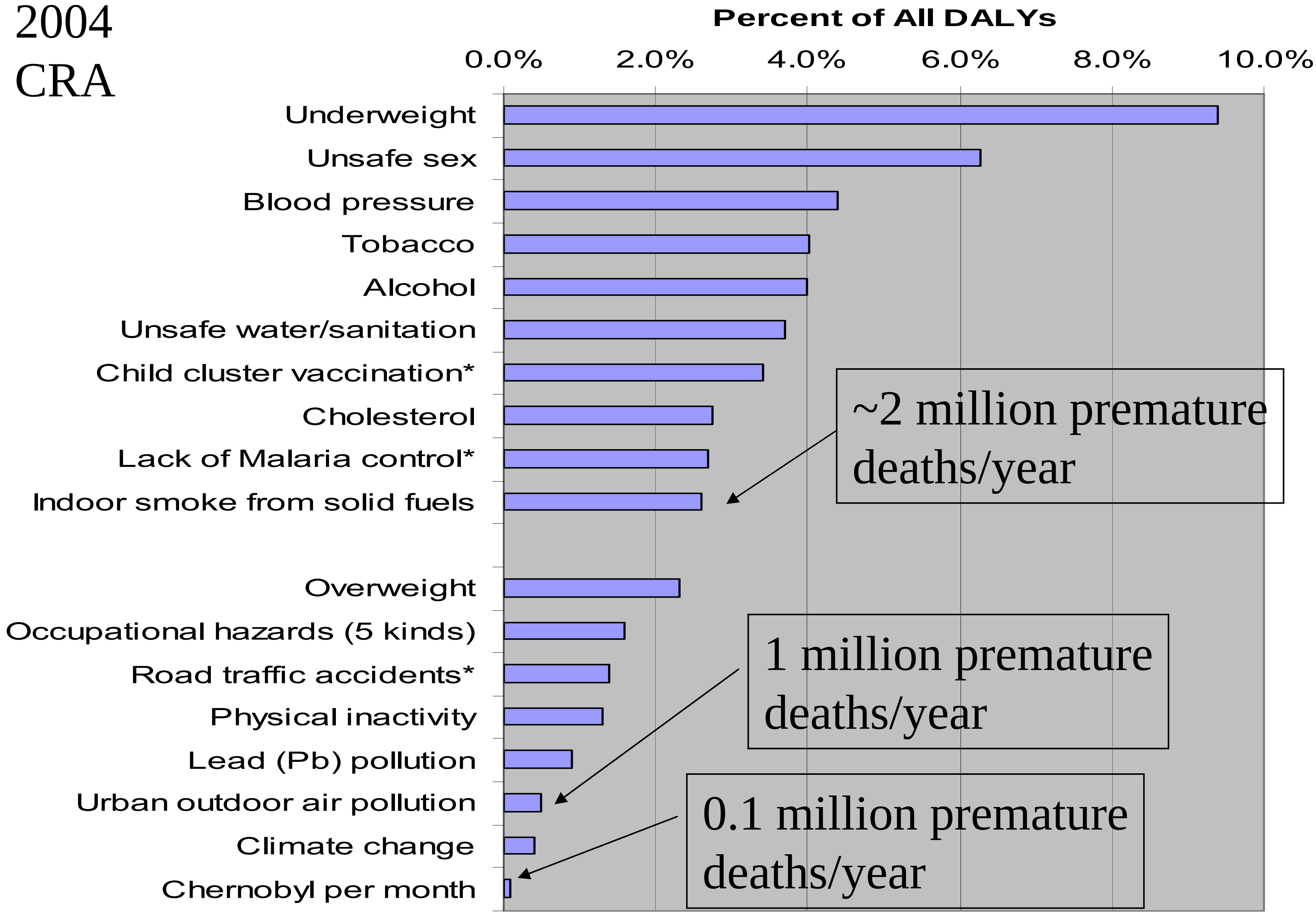
Lung cancer
(coal)

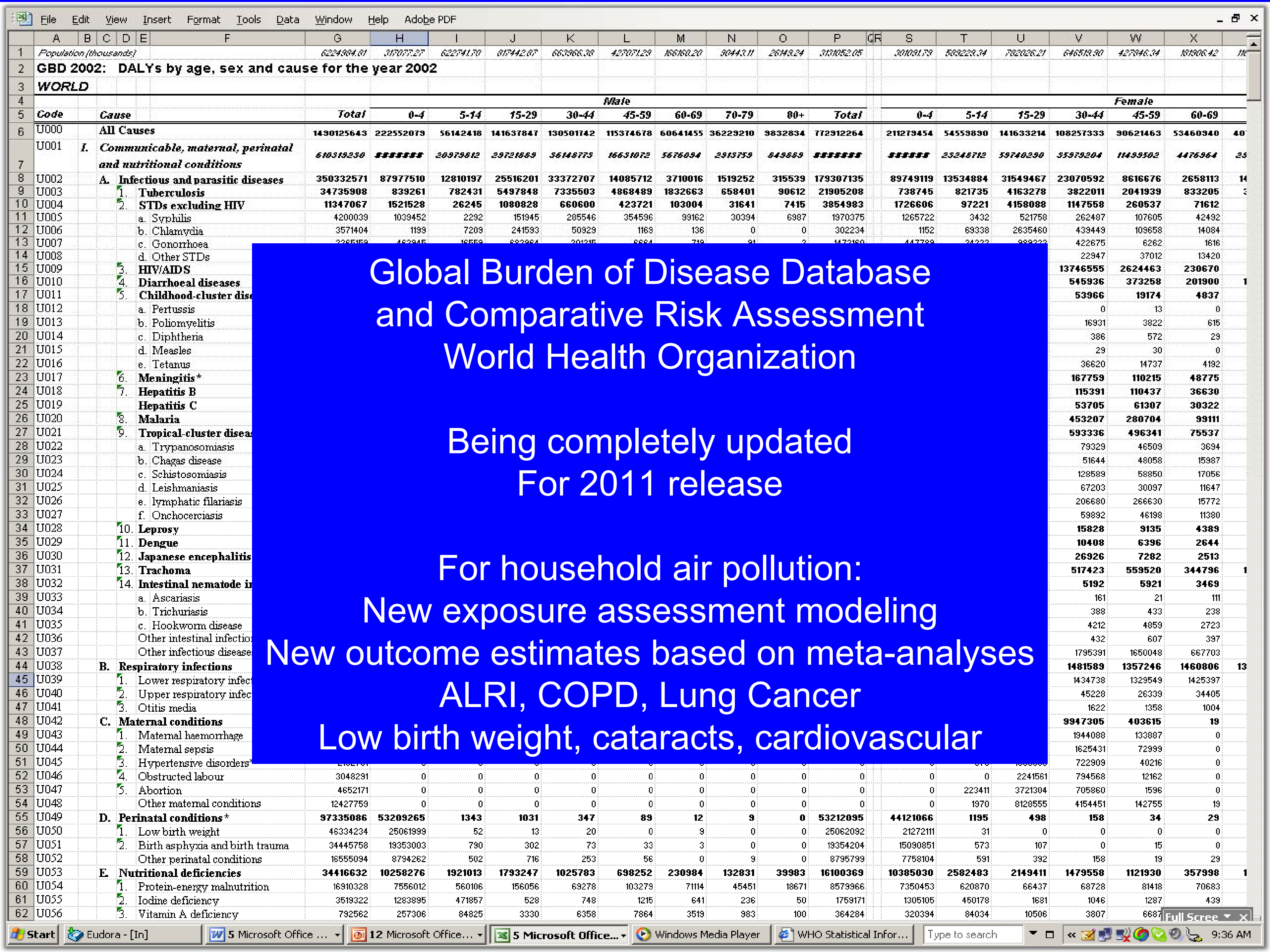
These three diseases were included in the
2004 Comparative Risk Assessment
Managed and published by WHO

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

2004
CRA





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

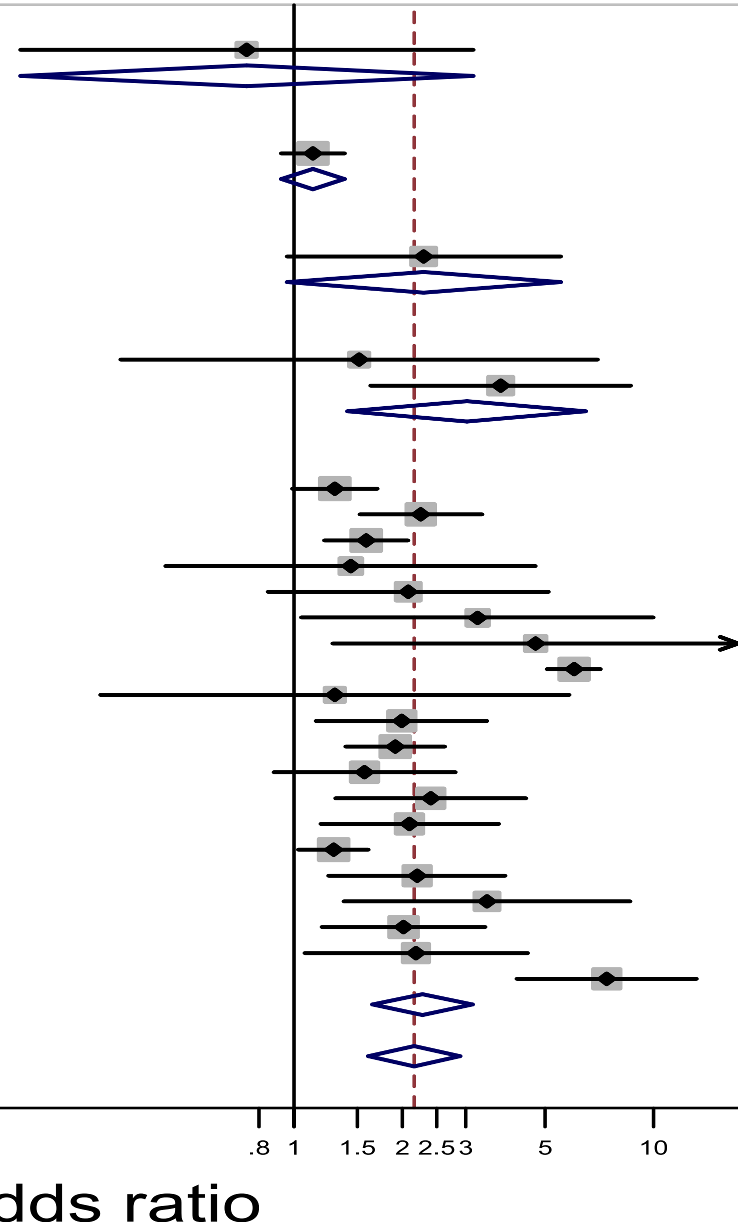
ALRI

Other cancers
(cervical, NP, upper airway)

Burns and the health/safety impacts of fuel gathering

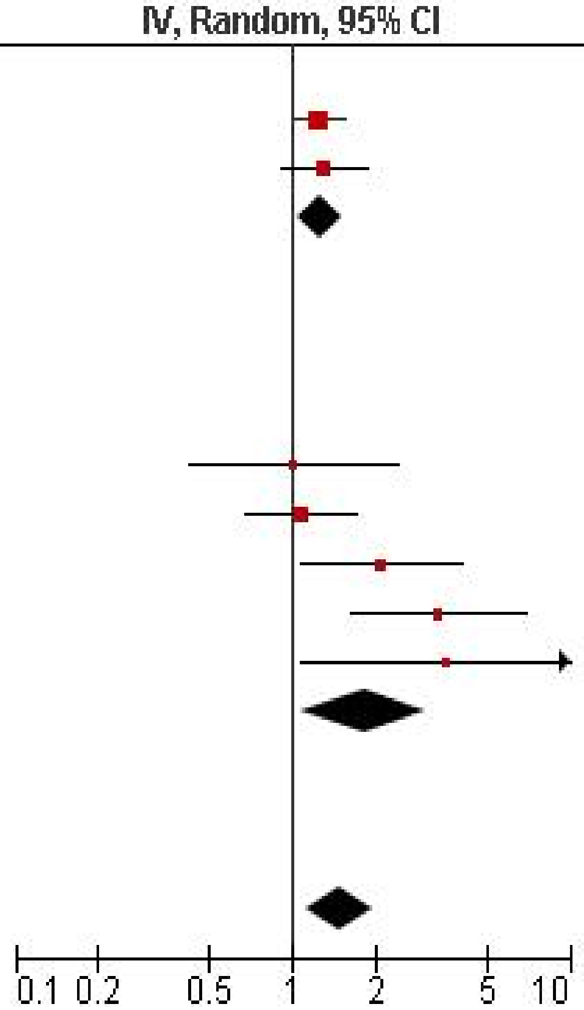
Summary risk estimates of lung cancer associated with in-home coal use for heating and cooking by geographic region

study	studyyear	casenum	contnum	ES (95% CI)
Africa				
Sasco(2002)	1996-1998	118	235	0.74 (0.17, 3.14)
Subtotal (I-squared = .%, p = .)				0.74 (0.17, 3.14)
.				
Europe				
Lissowska(2005)	1998-2001	2861	3118	1.13 (0.93, 1.38)
Subtotal (I-squared = .%, p = .)				1.13 (0.93, 1.38)
.				
North America				
Wu(1985)	1981-1982	220	220	2.30 (0.96, 5.50)
Subtotal (I-squared = .%, p = .)				2.30 (0.96, 5.50)
.				
India				
Gupta(2001)	1995-1997	265	525	1.52 (0.33, 6.98)
Sapkota(2008)	2001-2004	793	718	3.76 (1.64, 8.63)
Subtotal (I-squared = 4.4%, p = 0.307)				3.02 (1.42, 6.46)
.				
Mainland China and Taiwan				
Wu-Williams(1990)	1985-1987	965	959	1.30 (0.99, 1.70)
Sun(1991)	1985-1987	418	398	2.26 (1.53, 3.33)
Chengyu(1992)	1990-1991	135	135	1.59 (1.22, 2.07)
Ger(1993)	1990-1991	131	524	1.44 (0.44, 4.69)
Li(1993)	1986-1992	161	161	2.08 (0.85, 5.08)
Lin(1996)	1985-1990	122	122	3.24 (1.05, 9.94)
Dai(1996)	1992-1993	120	120	4.70 (1.29, 17.18)
Luo(1996)	1990-1991	102	306	6.00 (5.07, 7.10)
Ko(1997)	1992-1993	117	117	1.30 (0.29, 5.80)
Hao(1998)	1981-1986	220	440	1.99 (1.16, 3.43)
Huang(1999)	1993-1996	122	244	1.92 (1.40, 2.62)
Wu(1999)	1997	258	258	1.58 (0.89, 2.80)
Lan(2000)	1995-1996	122	122	2.40 (1.31, 4.40)
Lee(2001)	1993-1999	527	805	2.10 (1.19, 3.70)
Kleinerman(2002)	1994-1998	832	1724	1.29 (1.03, 1.61)
Sun(2002)	1996-1999	206	618	2.20 (1.25, 3.86)
Lu(2003)	1998-2001	445	445	3.44 (1.38, 8.57)
Liang(2004)	2001-2002	152	152	2.02 (1.20, 3.39)
Galeone(2008)	1987-1990	218	436	2.19 (1.08, 4.46)
Lan(2008)	1985-1990	498	498	7.40 (4.18, 13.10)
Subtotal (I-squared = 90.3%, p = 0.000)				2.28 (1.66, 3.13)
.				
Overall (I-squared = 90.4%, p = 0.000)				2.16 (1.62, 2.90)



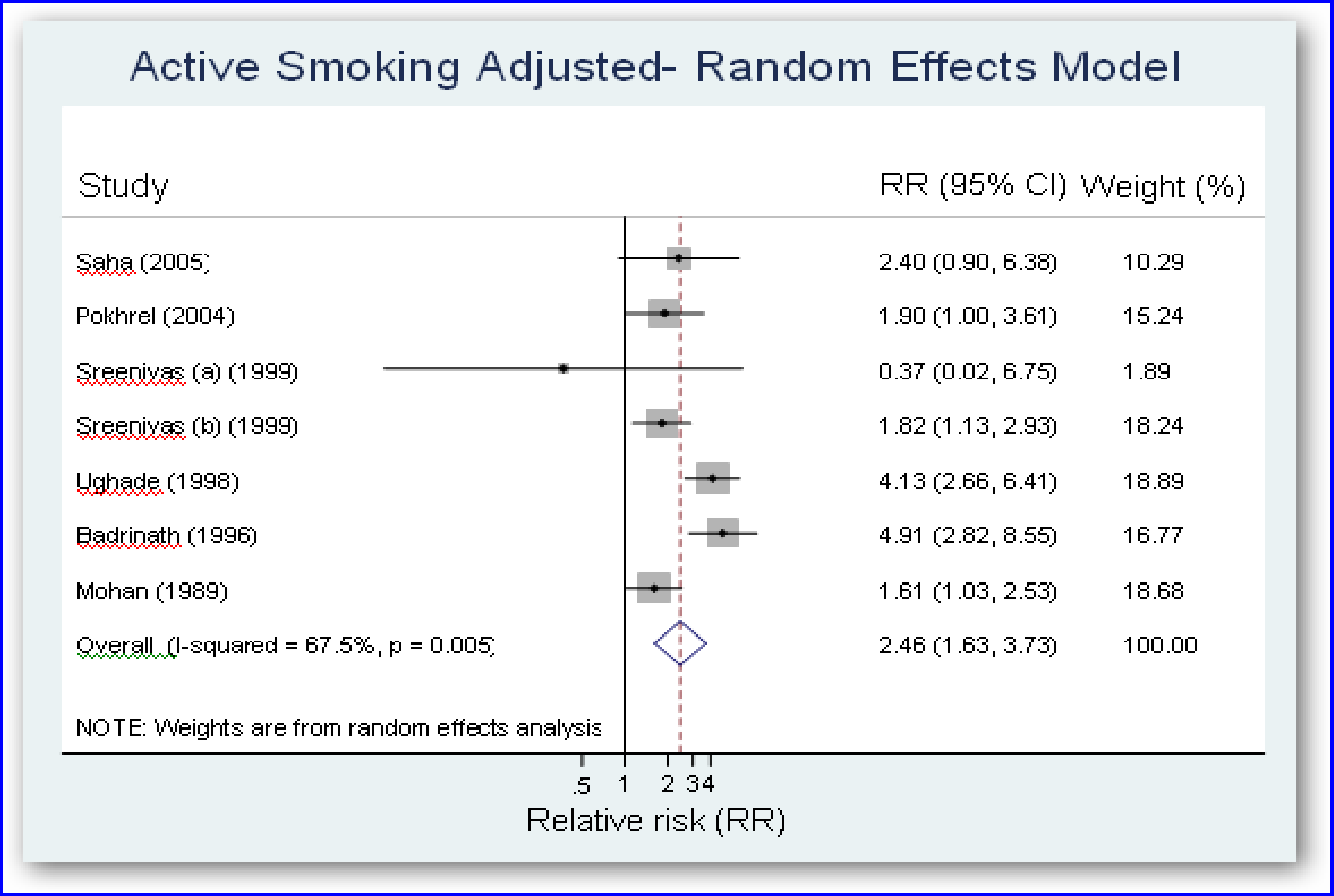
Lung Cancer: Biomass vs. clean fuel

Study or Subgroup	IV, Random, 95% CI
2.7.1 Male	
Lissowska2005	1.24 [1.00, 1.54]
Sapkota2008	1.30 [0.90, 1.87]
Subtotal (95% CI)	**1.26 [1.04, 1.52]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.05$, df = 1 (P = 0.83); $I^2 = 0\%$	
Test for overall effect: Z = 2.37 (P = 0.02)	
2.7.2 Female	
Sapkota2008	1.01 [0.42, 2.41]
Lissowska2005	1.07 [0.67, 1.71]
Ko1997	2.08 [1.06, 4.07]
Lee2001	3.36 [1.62, 6.96]
Behera 2005	3.59 [1.08, 11.97]
Subtotal (95% CI)	**1.81 [1.07, 3.06]**
Heterogeneity: $Tau^2 = 0.21$; $Chi^2 = 10.21$, df = 4 (P = 0.04); $I^2 = 61\%$	
Test for overall effect: Z = 2.20 (P = 0.03)	
Total (95% CI)	**1.48 [1.12, 1.97]**
Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 12.14$, df = 6 (P = 0.06); $I^2 = 51\%$	
Test for overall effect: Z = 2.75 (P = 0.006)	
Test for subgroup differences: $Chi^2 = 1.89$, df = 1 (P = 0.17), $I^2 = 47.1\%$	



CRA, Imran et al. preliminary

Cataracts and Biomass Cooking Smoke*



* Adjusted for UV

CRA Preliminary, Adair et al.

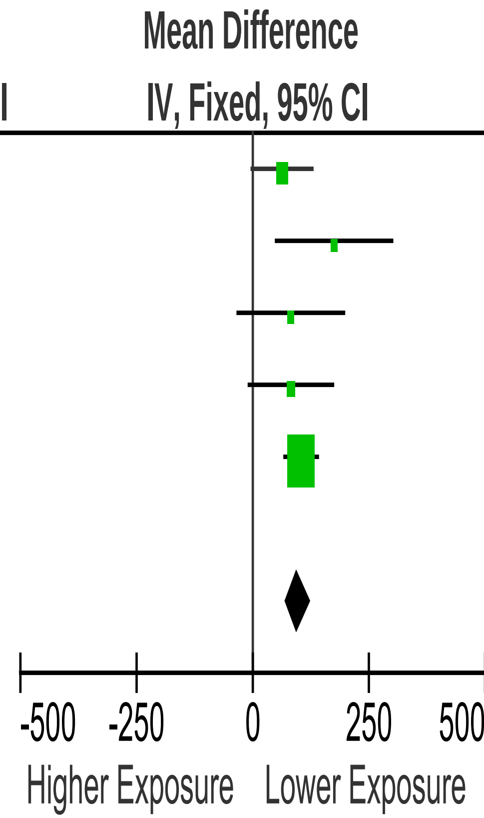
Pooled birth weight difference (low minus high exposure):

Adjusted estimates (Boy and Tielsch have GA)

	Lower Exposure			Higher Exposure				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	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)

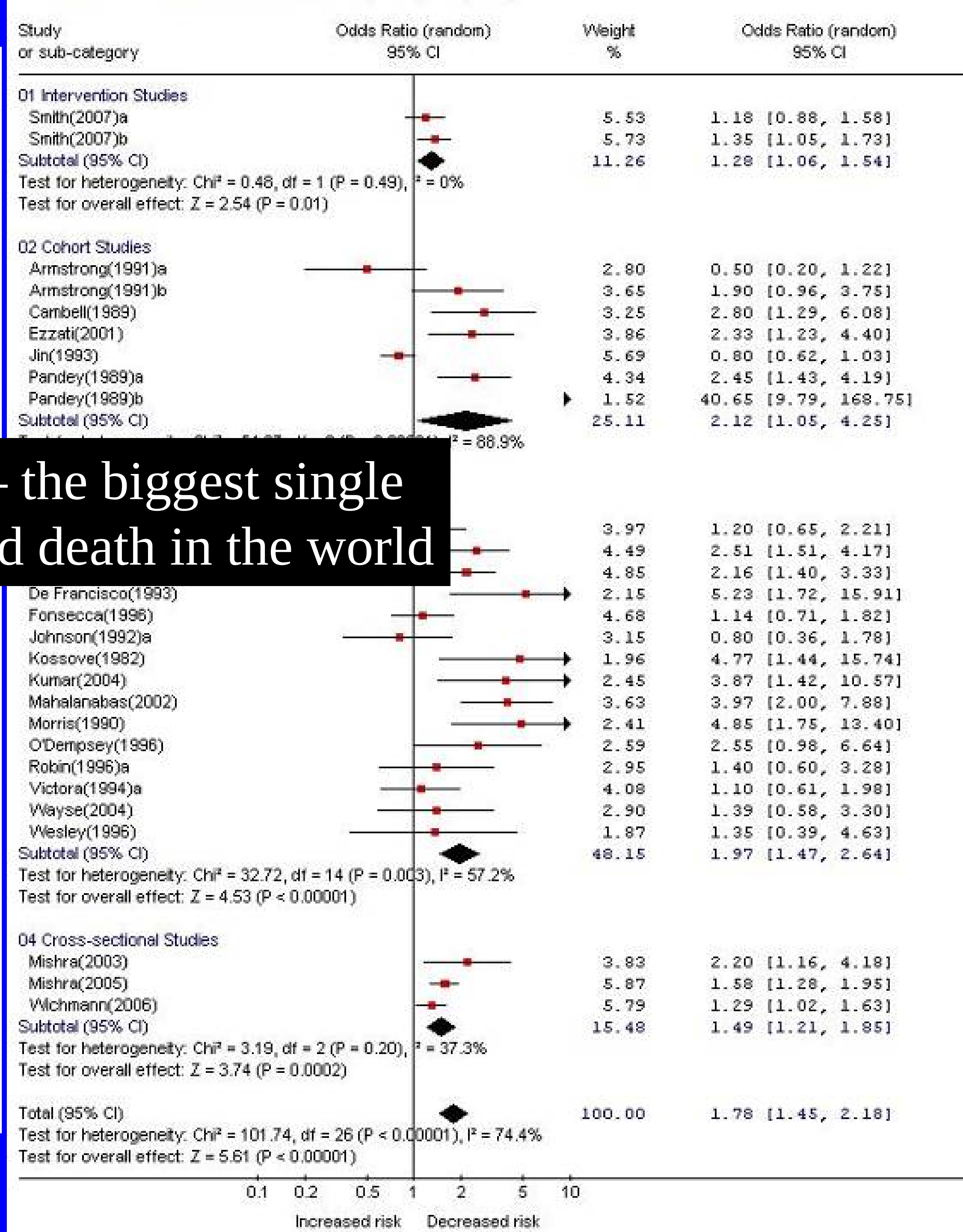
Excluding self-reports +93.1g (64.6, 121.6)

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	[illegible]	[illegible]
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



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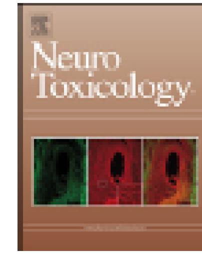
NeuroToxicology



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,*]

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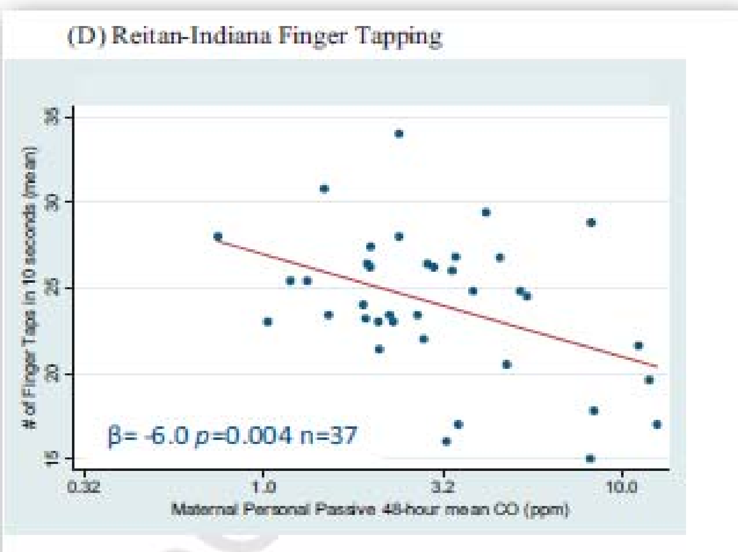
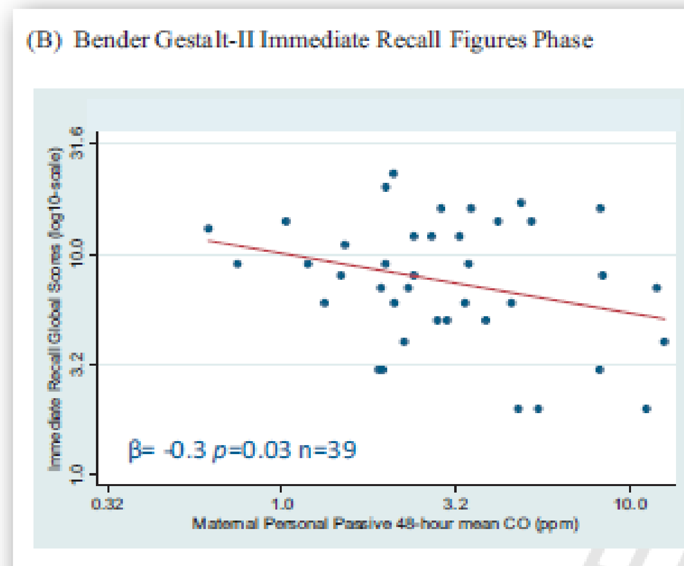
[d] Division of Occupational and Environmental Medicine, Department of Medicine, University of California, San Francisco, CA, USA





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]

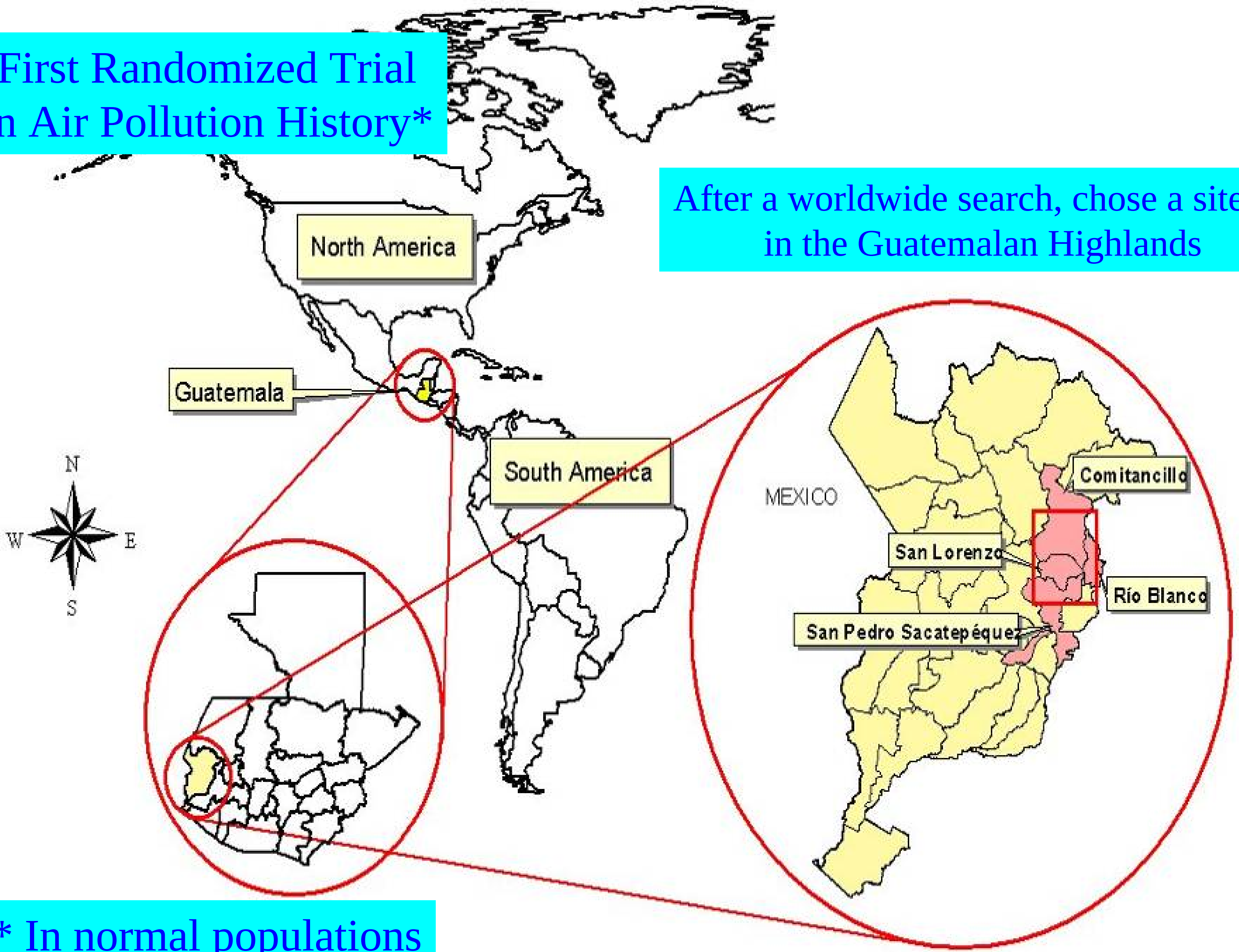
Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial

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

Published Nov 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 µg/m^3

Chimney wood stove, locally made and popular with households

Overview of RESPIRE study design

- 530 eligible households: open fire, woman pregnant or child less than 4 months
- Baseline survey and exposure assessment

Randomize

Keep open fire | *Plancha*

<u>Follow up till aged 18 months</u>

- Surveillance for ALRI, diarrhoea, &c
- Detailed exposure monitoring

Compare incidence and exposure in 2 groups
Plancha offered to ‘controls’

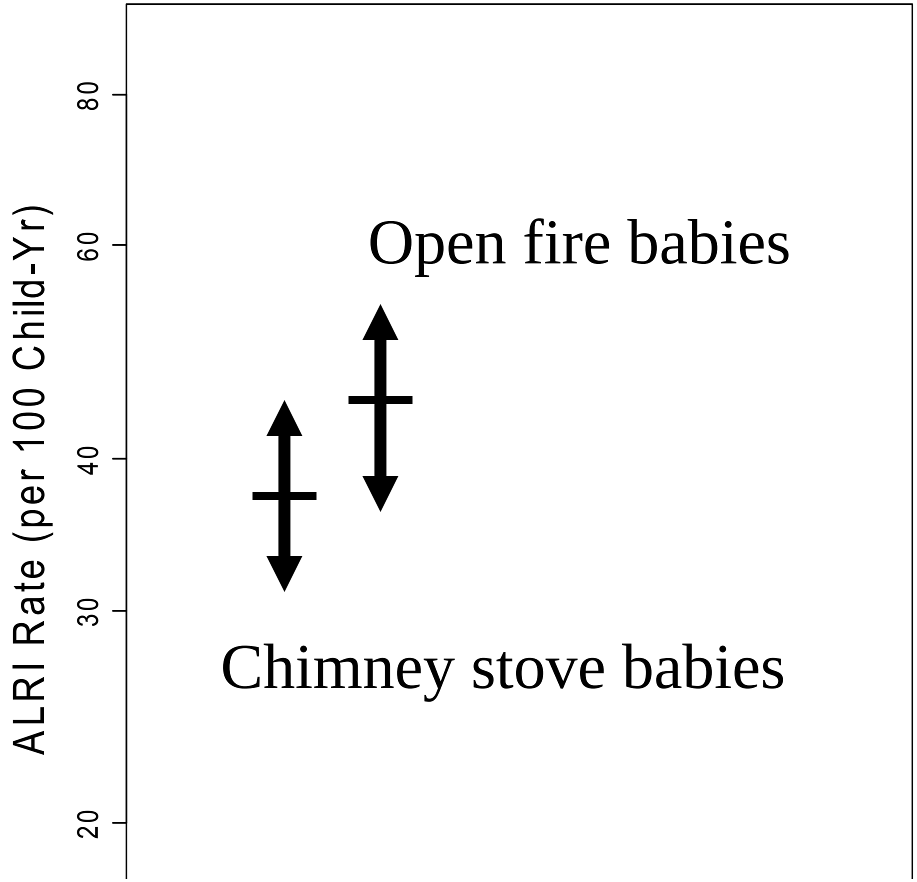
Year 1

5500 Households total

Years 1-3

Years 3-4

MD-diagnosed Acute Lower Respiratory Infection



RESPIRE-
Guatemala

0.78 (0.59, 1.06)	0.095

Fieldworker assessed outcomes:
ITT: 50% mean reduction in child exposure

AURI*	RR	95% CI	P-value
Cases of AURI	1.01	0.87, 1.17	0.88
Number of weeks with AURI	0.99	0.87, 1.12	0.87
ALRI (‘WHO Pneumonia’)	RR	95% CI	P-value
New cases: all	0.91	0.74, 1.13	0.39
New cases: severe**	**0.56**	**0.32, 0.97**	**0.04**

* Excludes evidence of pneumonia based on FW and physician assessment

** Severe: ill with cough or difficulty breathing <u>and</u> chest wall indrawing <u>and/or</u> unable to drink / breast feed

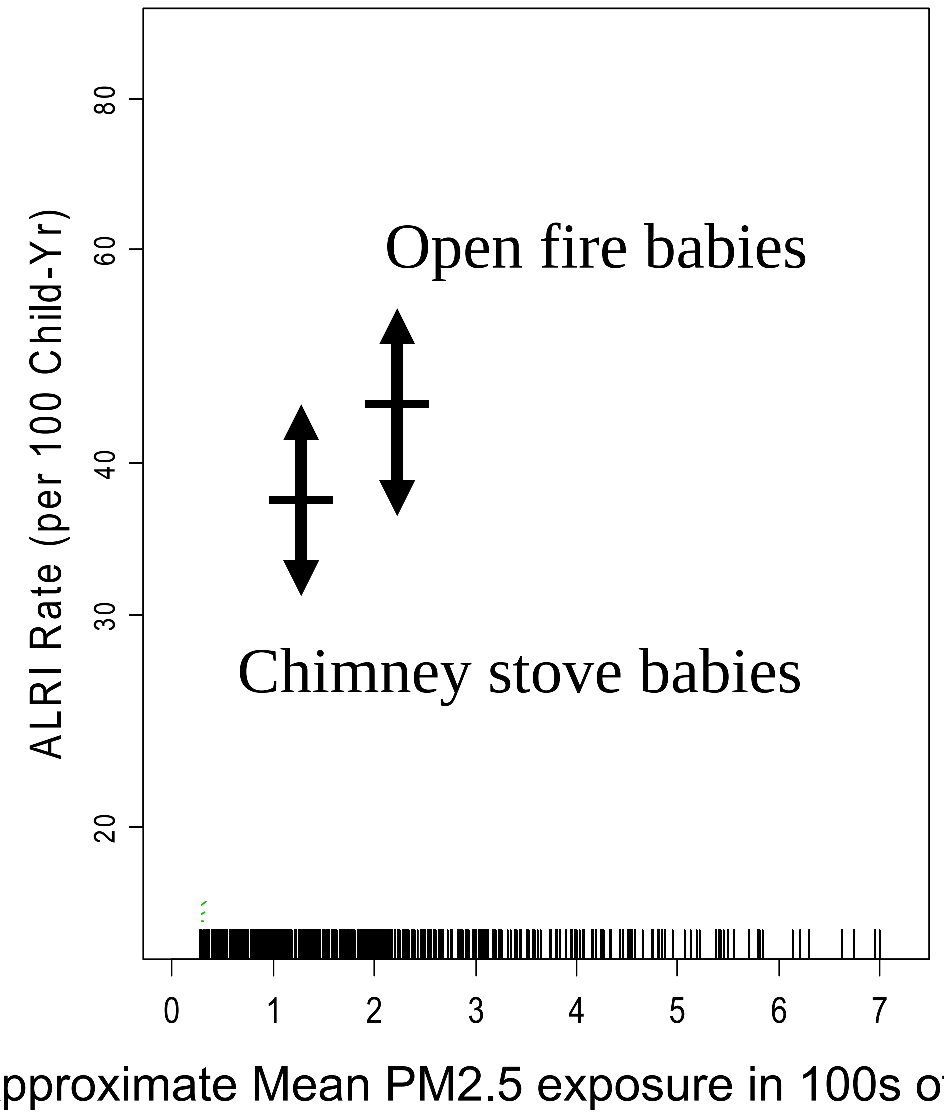
Physician-assessed outcomes (ITT)

(blind to intervention status)

Case finding	Outcome	adj RR (95% CI)	P-value
Physician diagnosed pneumonia	**All**	0.78 (0.59, 1.06)	0.095
	- Severe (hypoxic)	**0.67 (0.45, 0.98)**	**0.042**
	CXR +ve	0.74 (0.42, 1.15)	0.231
Investigations:	- CXR +ve & hypoxic	0.68 (0.36, 1.33)	0.234
- Pulse oximetry	**RSV +ve**	0.76 (0.42, 1.16)	0.275
- RSV direct antigen test	- RSV +ve & hypoxic	0.87 (0.46, 1.51)	0.633
	RSV -ve	0.79 (0.53, 1.07)	0.192
- Chest X-ray	- RSV –ve & hypoxic	**0.54 (0.31, 0.91)**	**0.026**


CO monitor
CO monitor

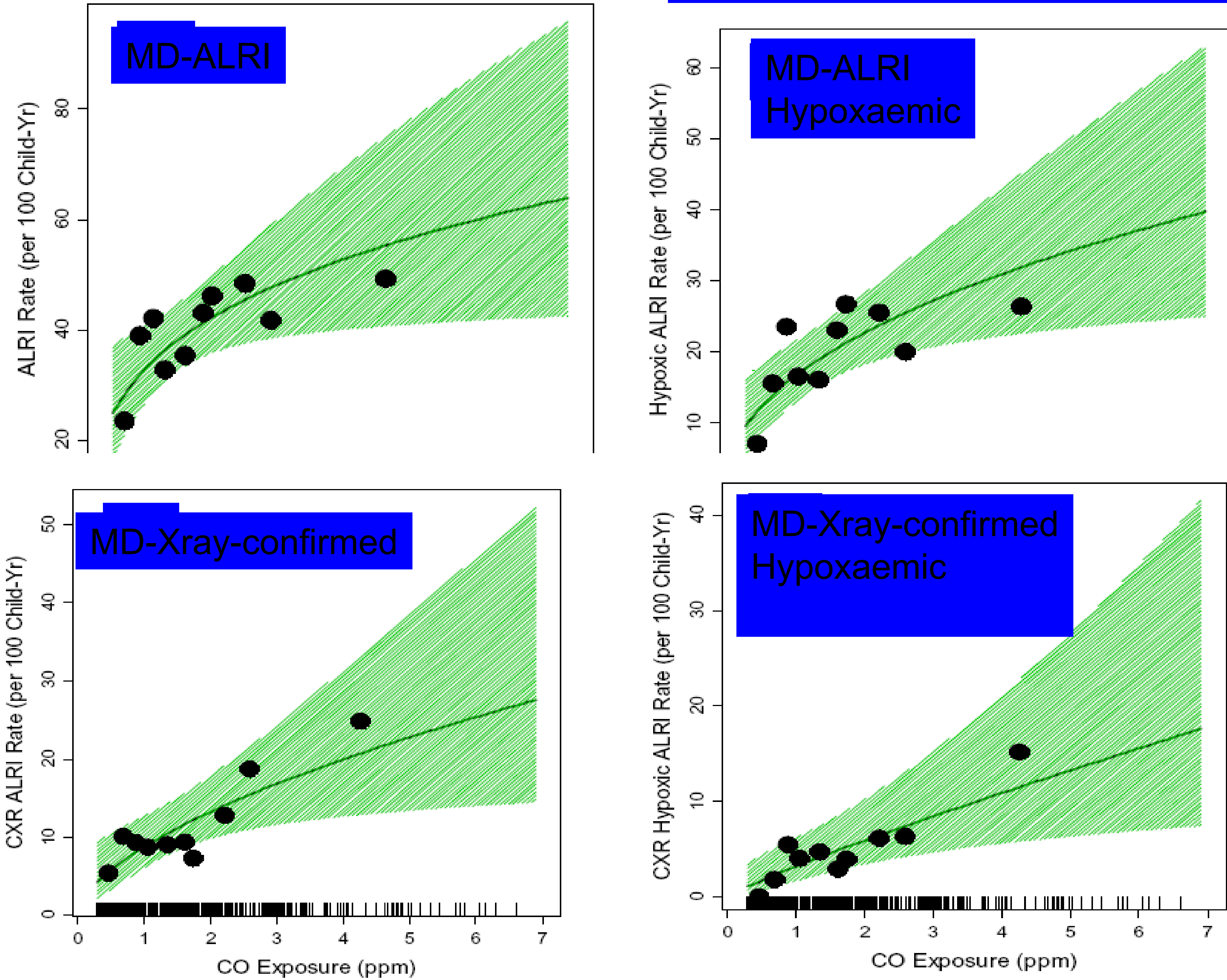
MD-diagnosed Acute Lower Respiratory Infection



RESPIRE-Guatemala

Adjustments for Exposure-Response Model

- Adjusted for child's age (quadratic), sex, birth interval less than 2 yr (yes/no), mother's age (quadratic), maternal education and paternal education (none/primary/ secondary), secondhand tobacco smoke exposure (yes/no), latrine (yes/no), piped water (yes/no), electricity (yes/no), kerosene lamp (yes/no), wood-fired sauna (yes/no), bedroom in kitchen (yes/no), roof type (metal sheet/tiles/straw), earth floor (yes/no), asset index (linear over range 0 to 6), animal ownership index (linear over range 0 to 4), crowding index (people per room), altitude (5 categories), occupation (farm other land/farm own land/other), and season (cold dry, warm wet, warm dry).

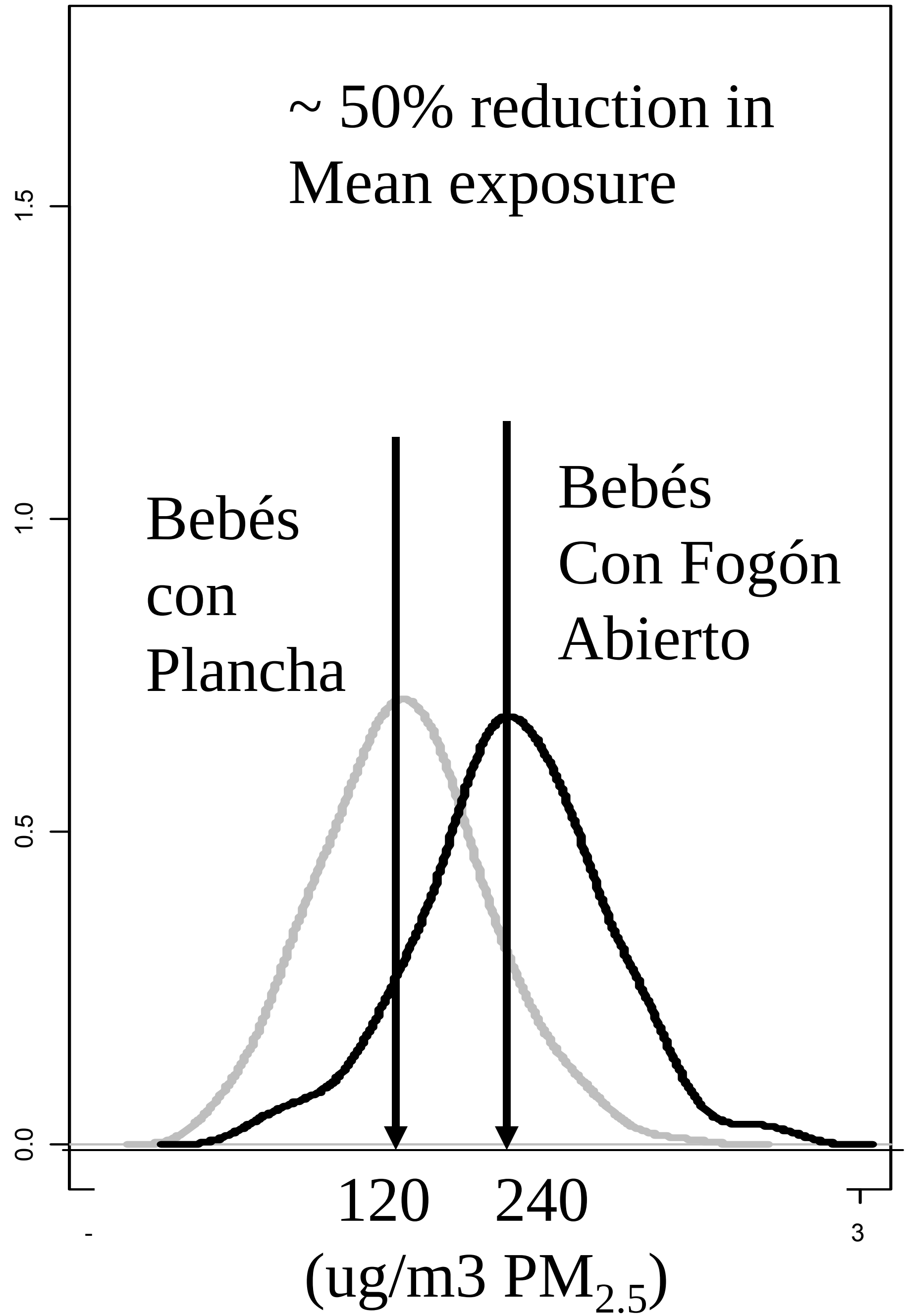


MD-ALRI
ALRI Rate (per 100 Child-Yr)
20
40
60
80
MD-ALRI
Hypoxaemic
Hypoxic ALRI Rate (per 100 Child-Yr)
10
20
30
40
50
60
MD-Xray-confirmed
CXR ALRI Rate (per 100 Child-Yr)
0
10
20
30
40
50
0 1 2 3 4 5 6 7
CO Exposure (ppm)
MD-Xray-confirmed
Hypoxaemic
CXR Hypoxic ALRI Rate (per 100 Child-Yr)
0
10
20
30
40
0 1 2 3 4 5 6 7
CO Exposure (ppm)

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)

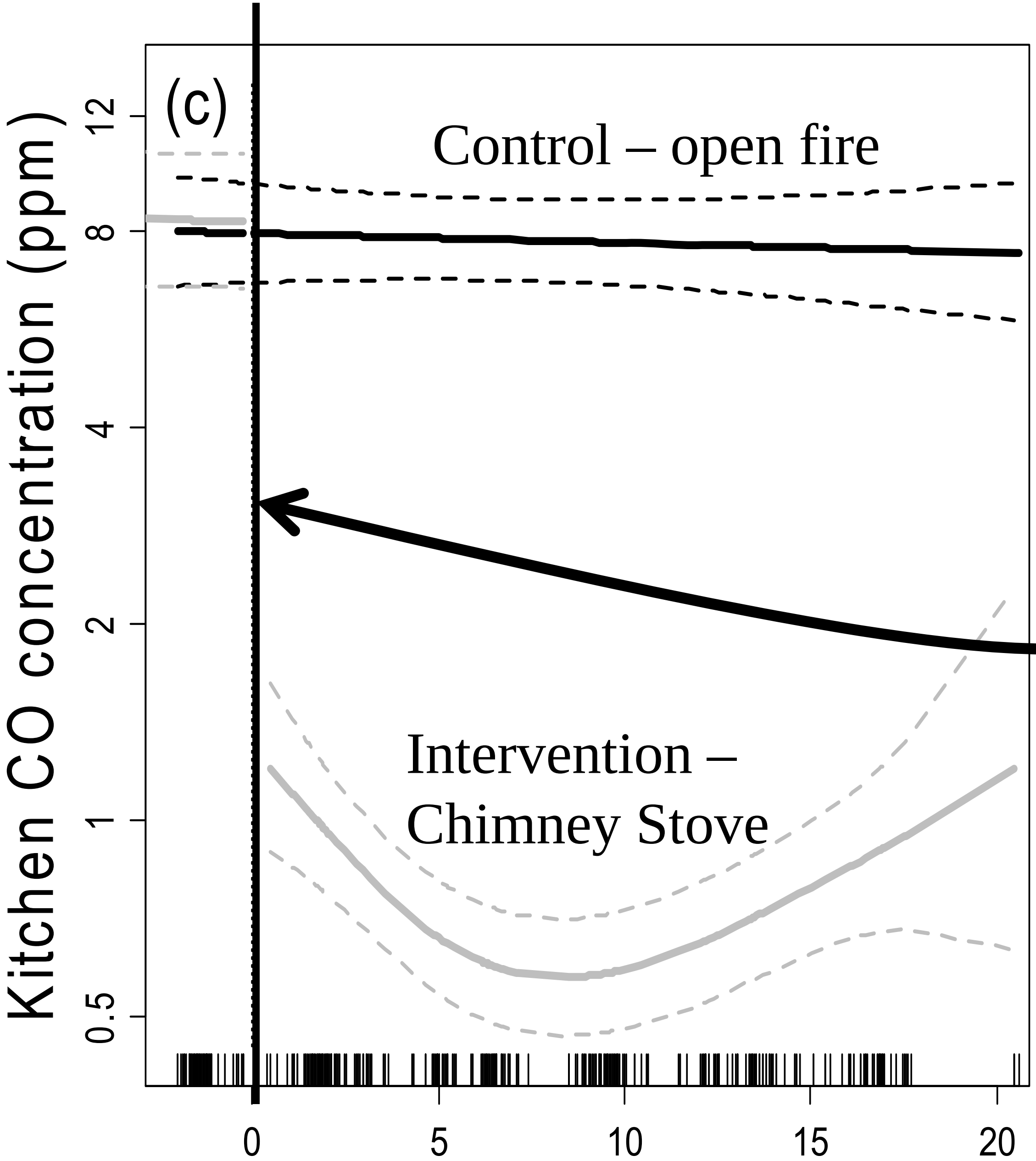
(b)



Chimney stove did not protect all babies

McCracken et al. 2009

Guatemala RCT: Kitchen Concentrations



Effect of Chimney Stove On Kitchen CO Levels

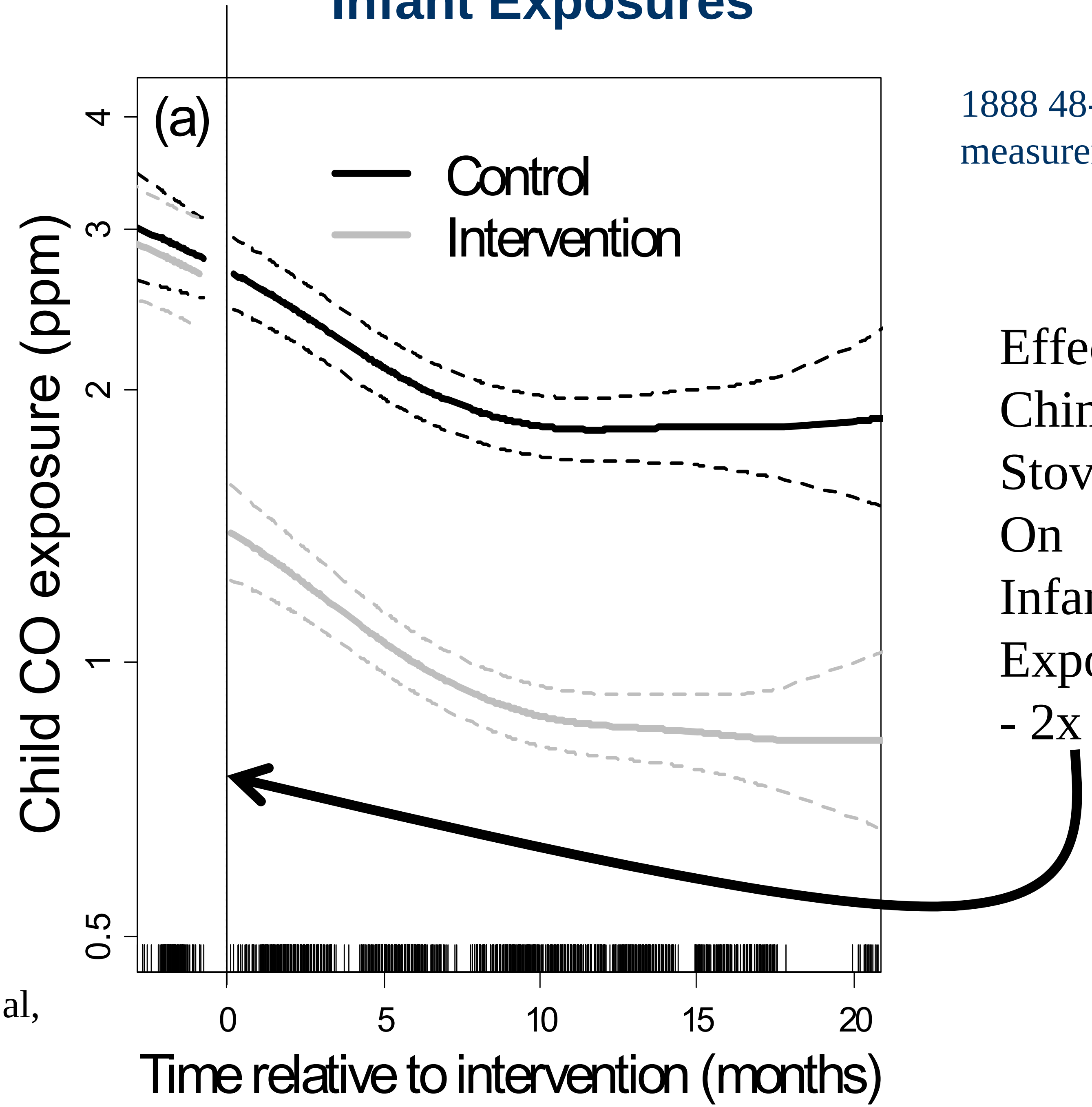
Factor of ~10 less

285 48-h measurements

Months

Smith, et al, 2010

Infant Exposures



1888 48-h measurements

Effect of Chimney Stove On Infant Exposures - 2x less

Smith, et al, 2010

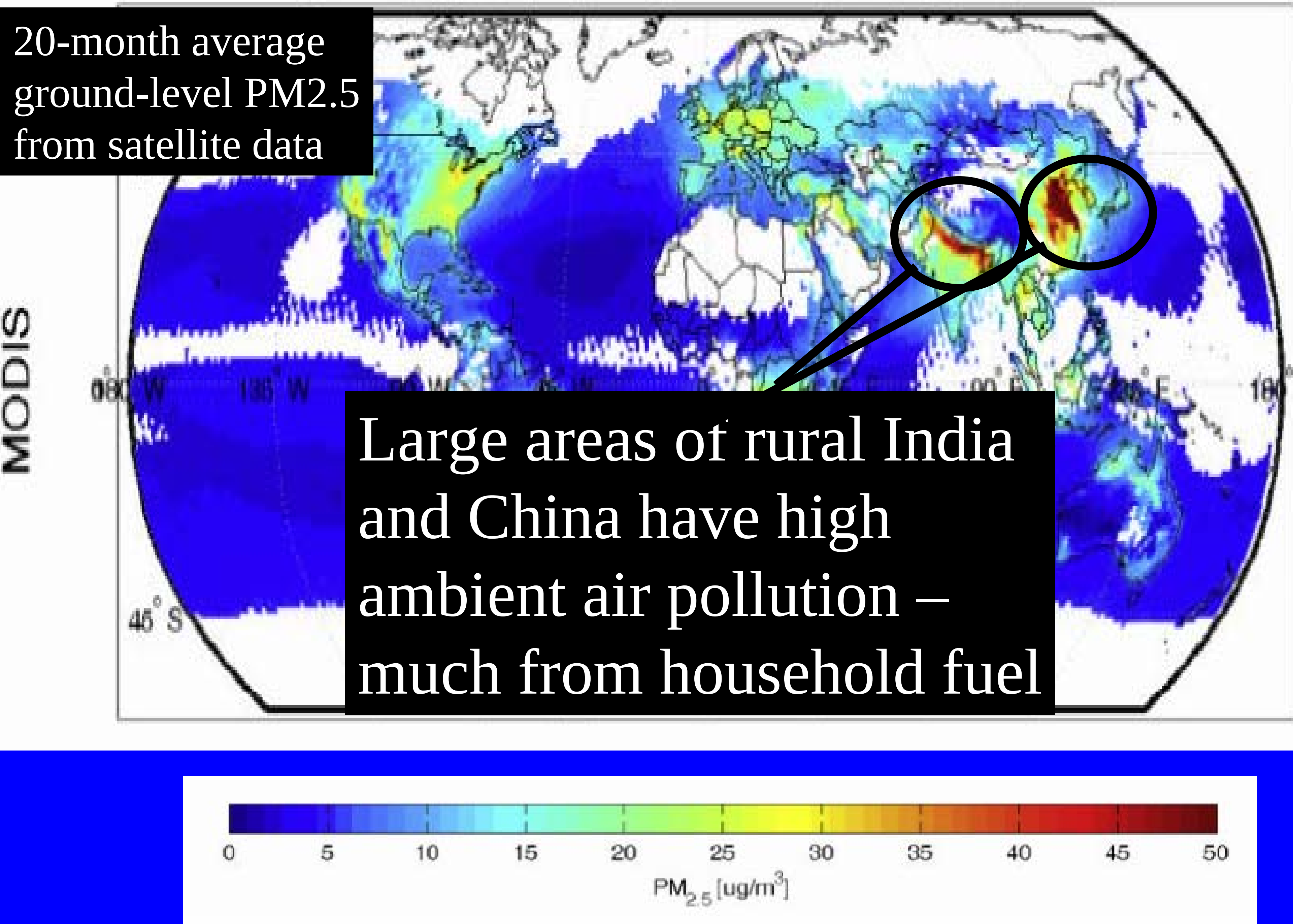
RESPIRE Summary

- Results - ITT
  - Chimney stove did not reduce all MD pneumonia,
  - But did reduce severe MD pneumonia and
  - RSV-negative (bacterial pneumonia)
  - Even though well operating, chimney was not capable of sufficient exposure reduction by itself
- Results – Exposure-response
  - All major outcome showed significant results (still not RSV pneumonia)
  - Partial exposure reduction brings some benefit, but ER curve highly non-linear
  - Large reductions needed for substantial health benefits – levels not possible with chimneys

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

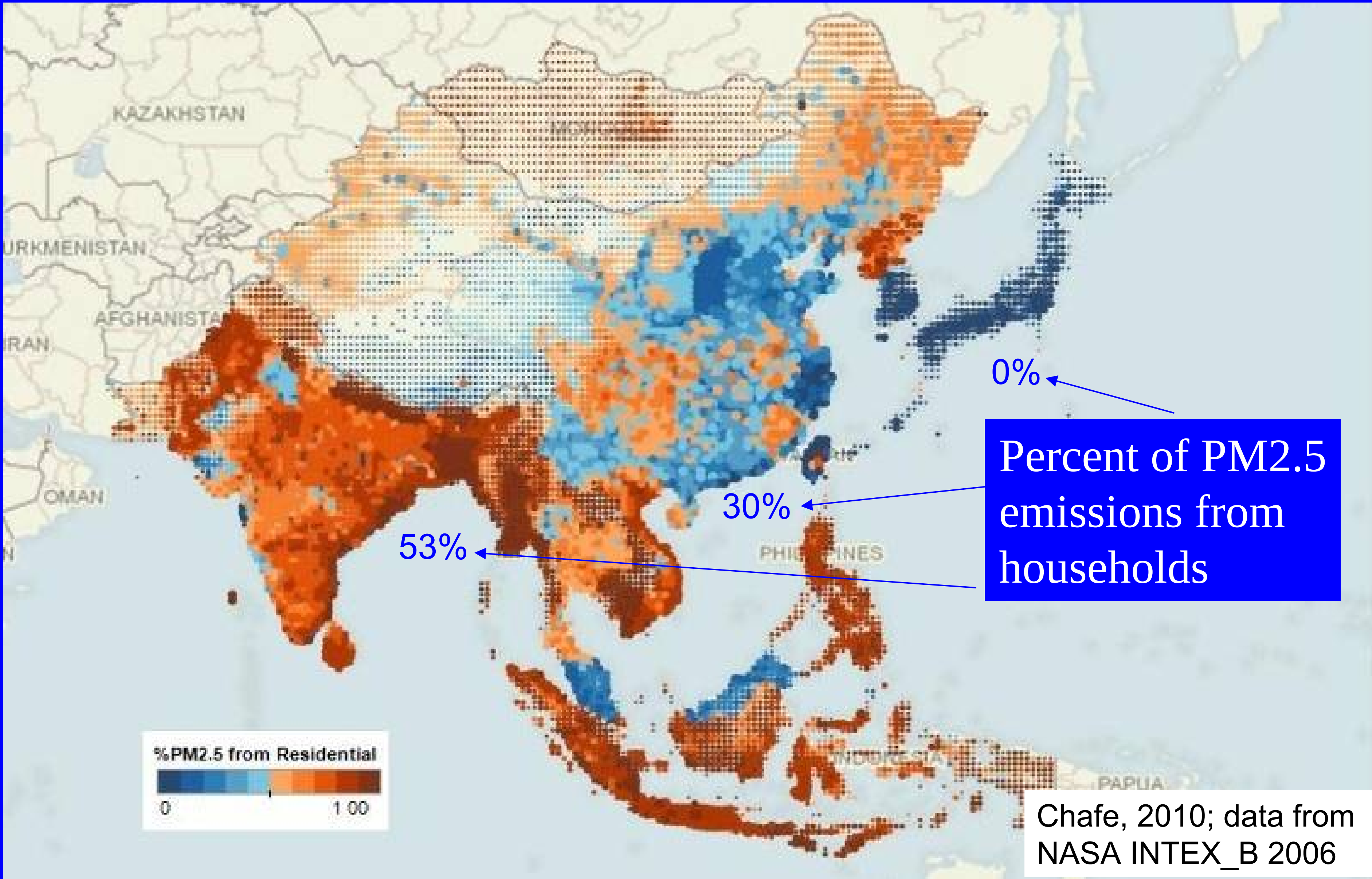
- --Time-activity: the kids do not spend their entire day in the kitchen
- --Household (or “neighborhood”) pollution: a chimney does not reduce smoke, but just shifts it outside into the household environment, where the difference between intervention and control households was less
- --No significant difference in bedrooms

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



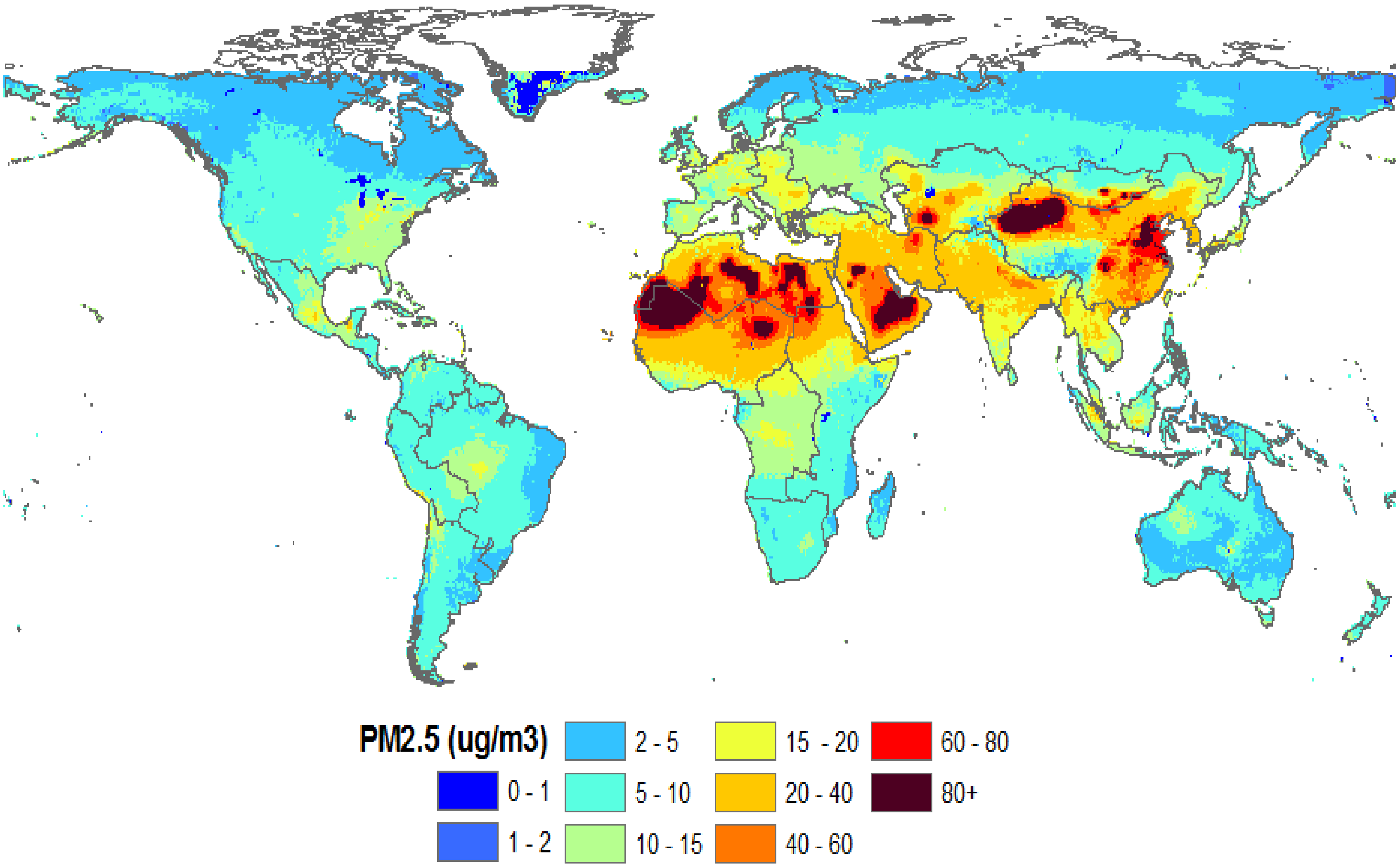
Large areas of rural India and China have high ambient air pollution – much from household fuel

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



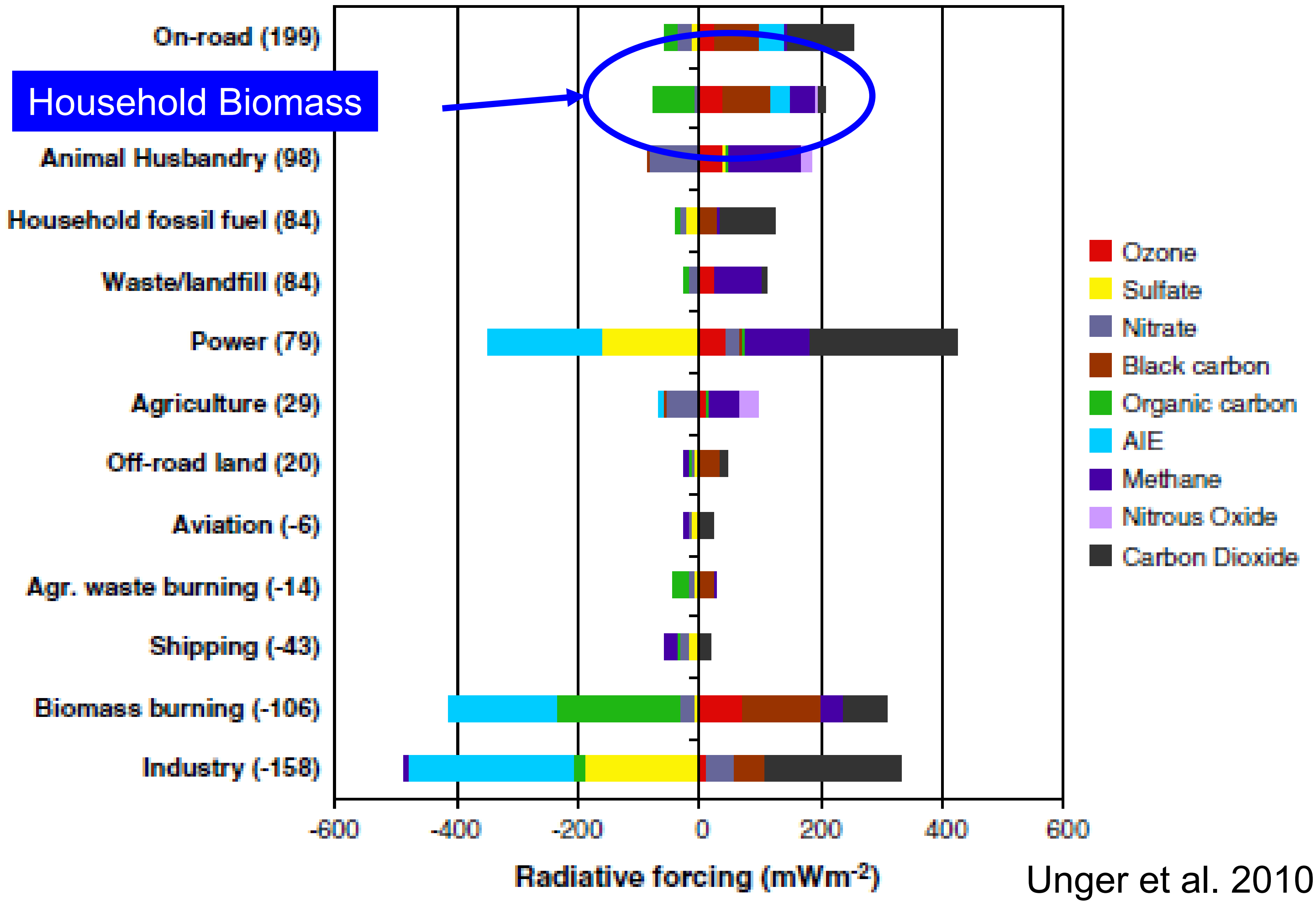
Chafe, 2010; data from NASA INTEX_B 2006

Mean $PM_{2.5}$ in 2005



Brauer et al. EST 2011

Climate Warming in 2020 Under Present Trends



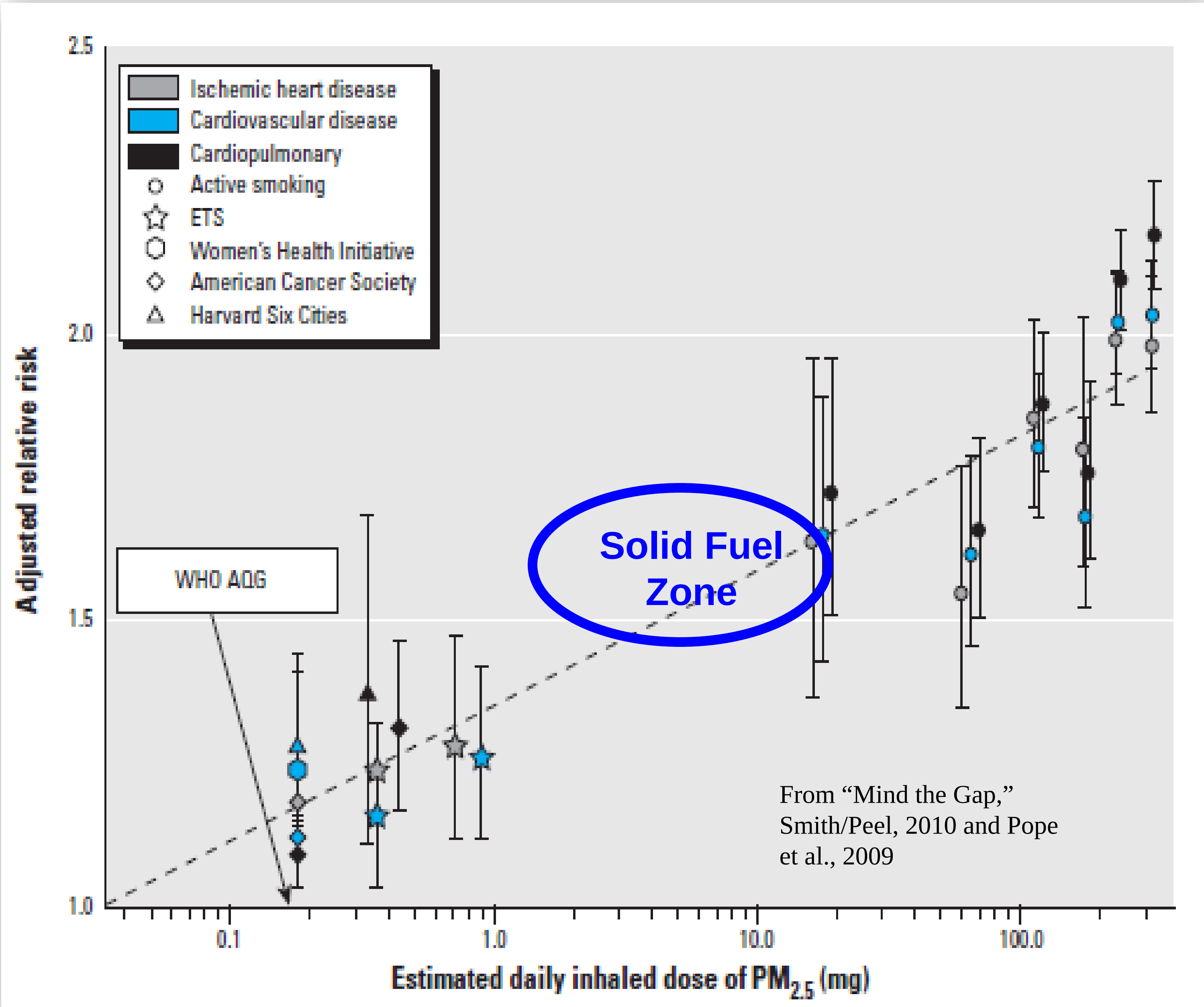
Unger et al. 2010

Combustion Particles

The Generalized Exposure Response

(GER)

Heart Disease and Combustion Particle Doses



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.

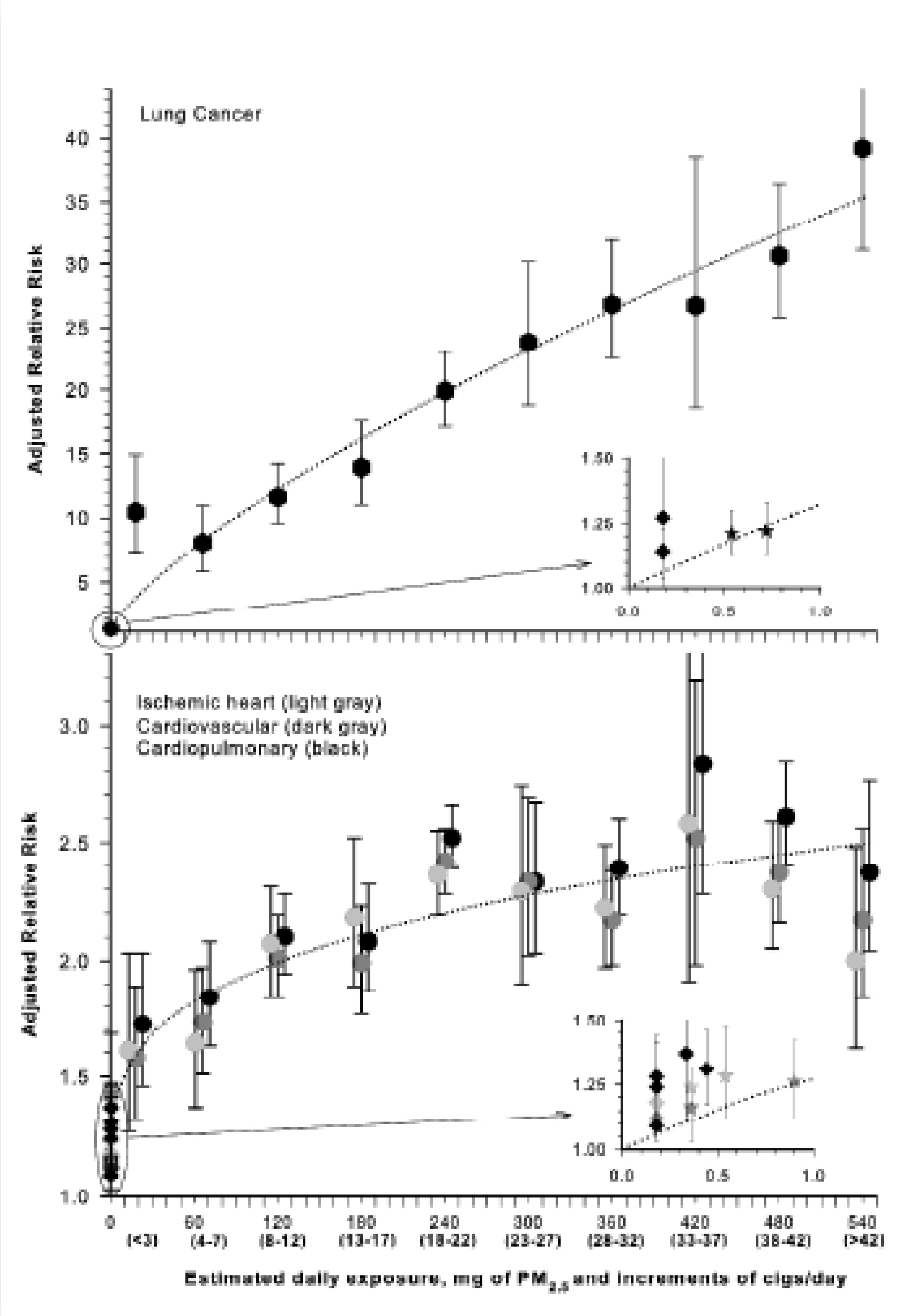
	Crude		Adjusted	
Comparison	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value
Between-groups	0.34 (0.15, 0.81)	0.015	0.26 (0.08, 0.90)[a]	0.033
Before-and-after (only control group)	0.41 (0.24, 0.70)	0.001	0.28 (0.12, 0.63)[b]	0.002

[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).

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 μg/m^3 ambient $PM_{2.5}$	-----	-----	-----	1.31(1.17-1.46)	0.44
ACS-air pol. extend.	10 μg/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 μg/m^3 ambient $PM_{2.5}$	-----	-----	-----	1.37(1.11-1.68)	0.33
HSC-air pol. extend.	10 μg/m^3 ambient $PM_{2.5}$	1.21(0.92-1.69)	-----	1.28(1.13-1.44)	-----	0.18
WHI-air pol.	10 μg/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

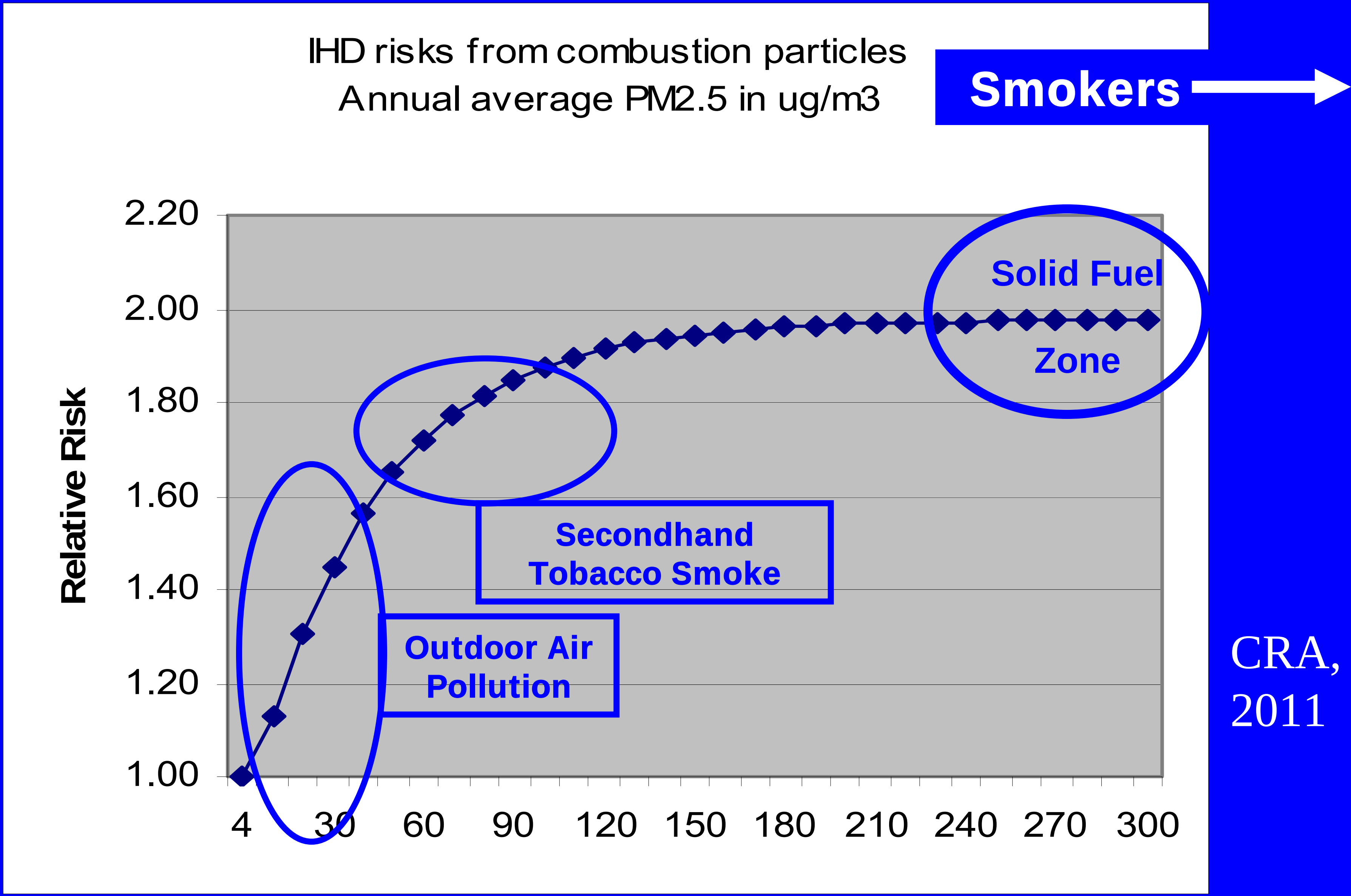


Lung Cancer

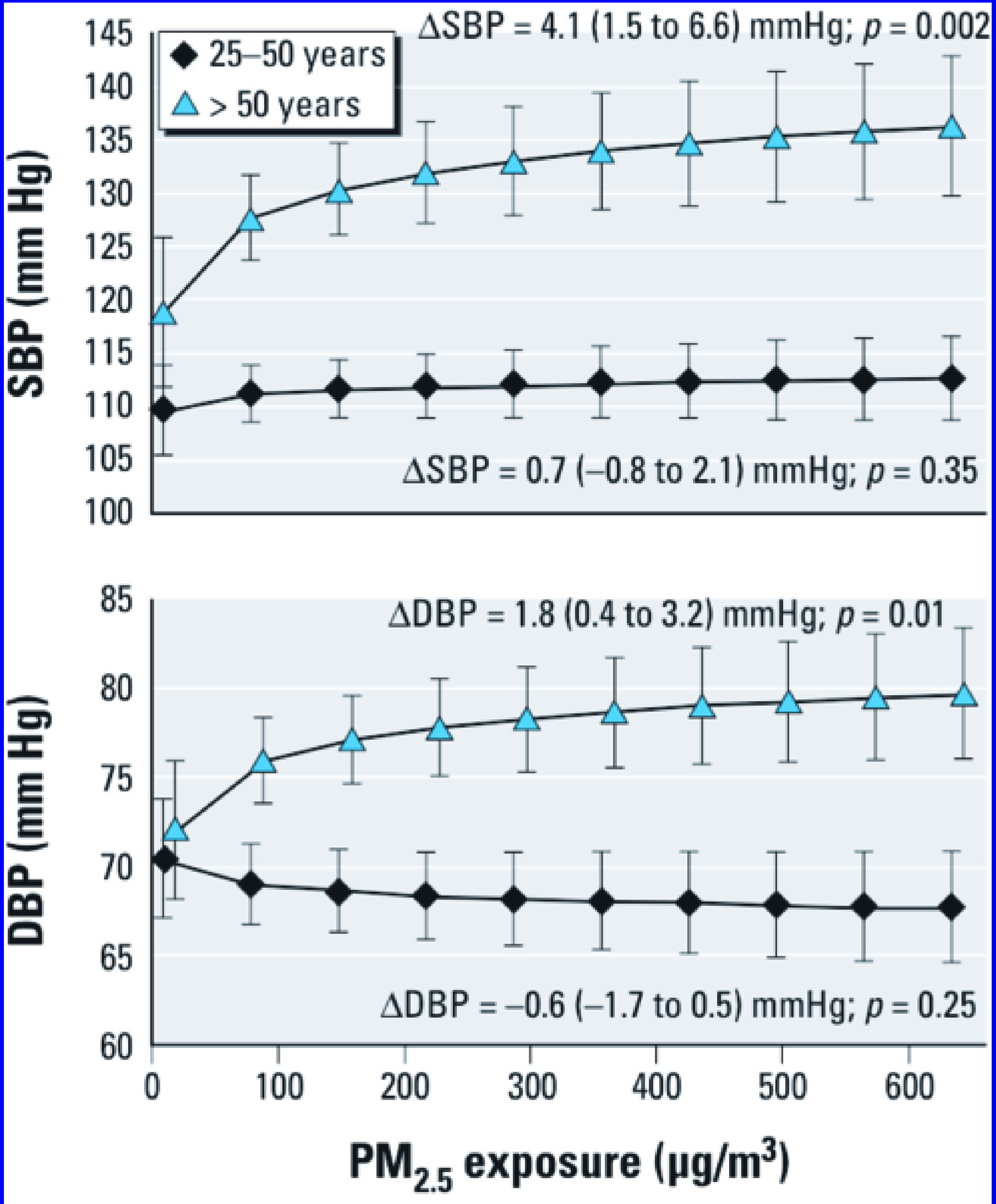
Heart Disease

Pope et al. Environmental Health Perspectives 2011, in press

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



CRA, 2011

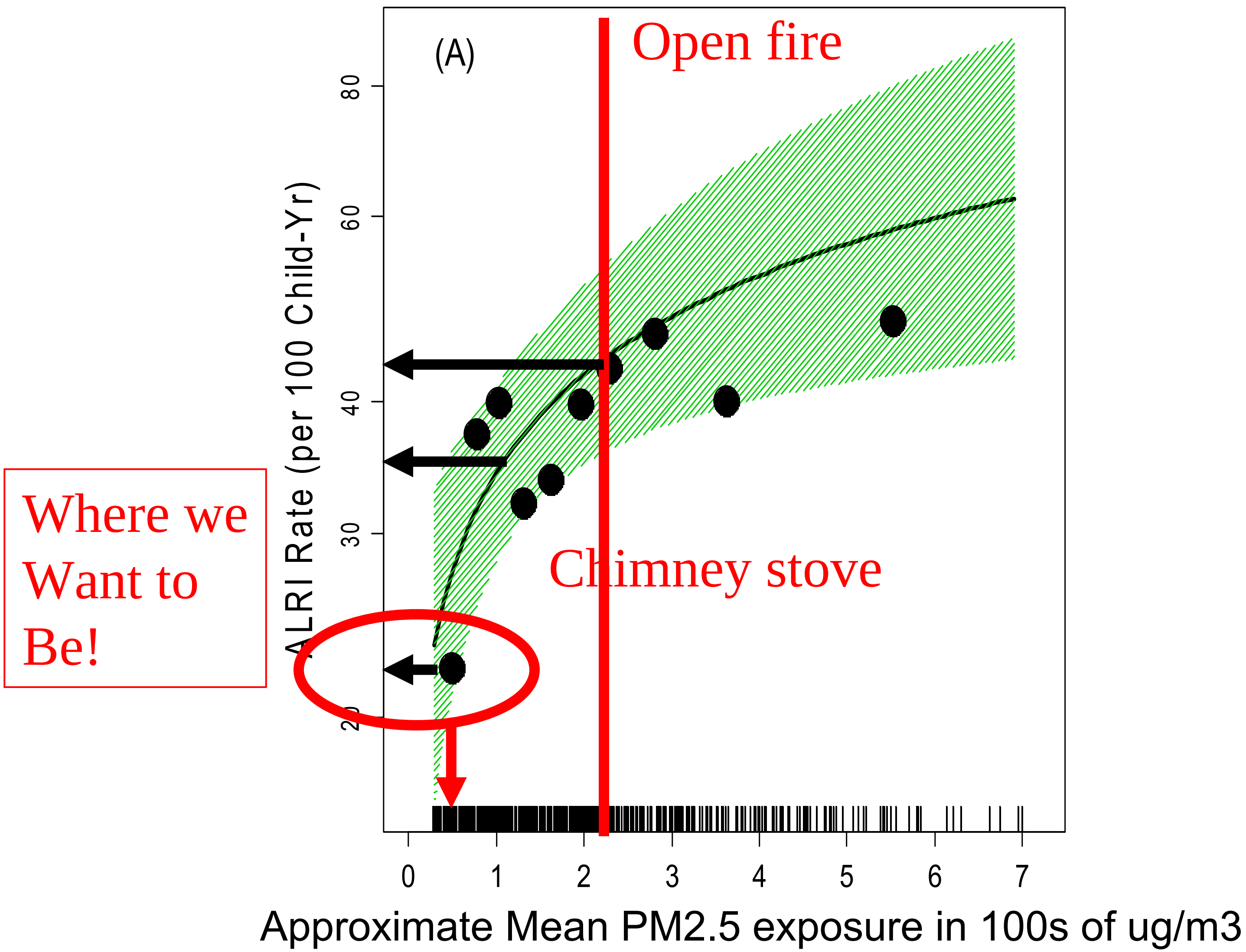


Household Air Pollution and Blood Pressure

In Yunnan

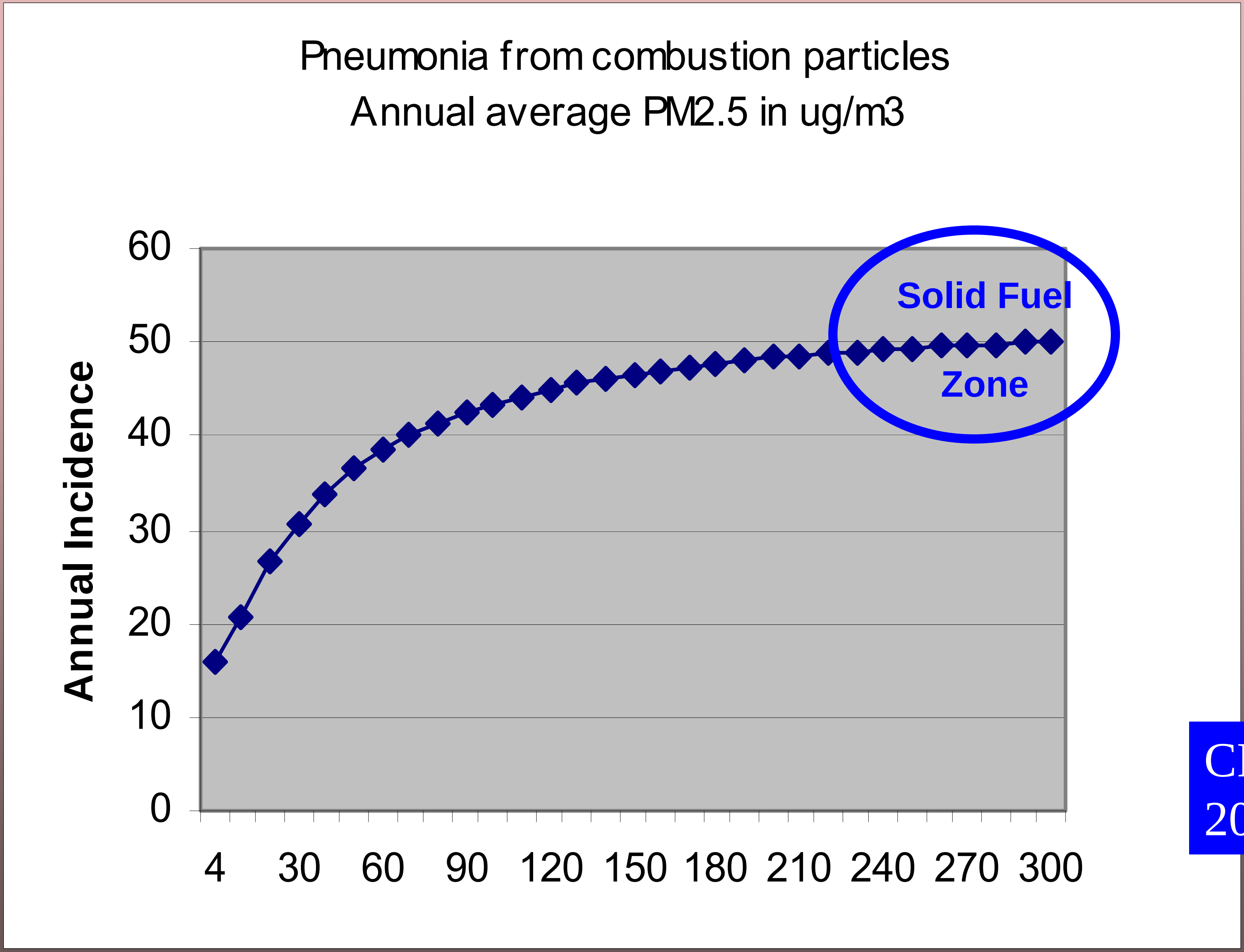
Baumgartner et al.
Environmental Health Perspectives 2011, Oct

MD-diagnosed Acute Lower Respiratory Infection



RESPIRE-Guatemala

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



CRA, 2011

Summary

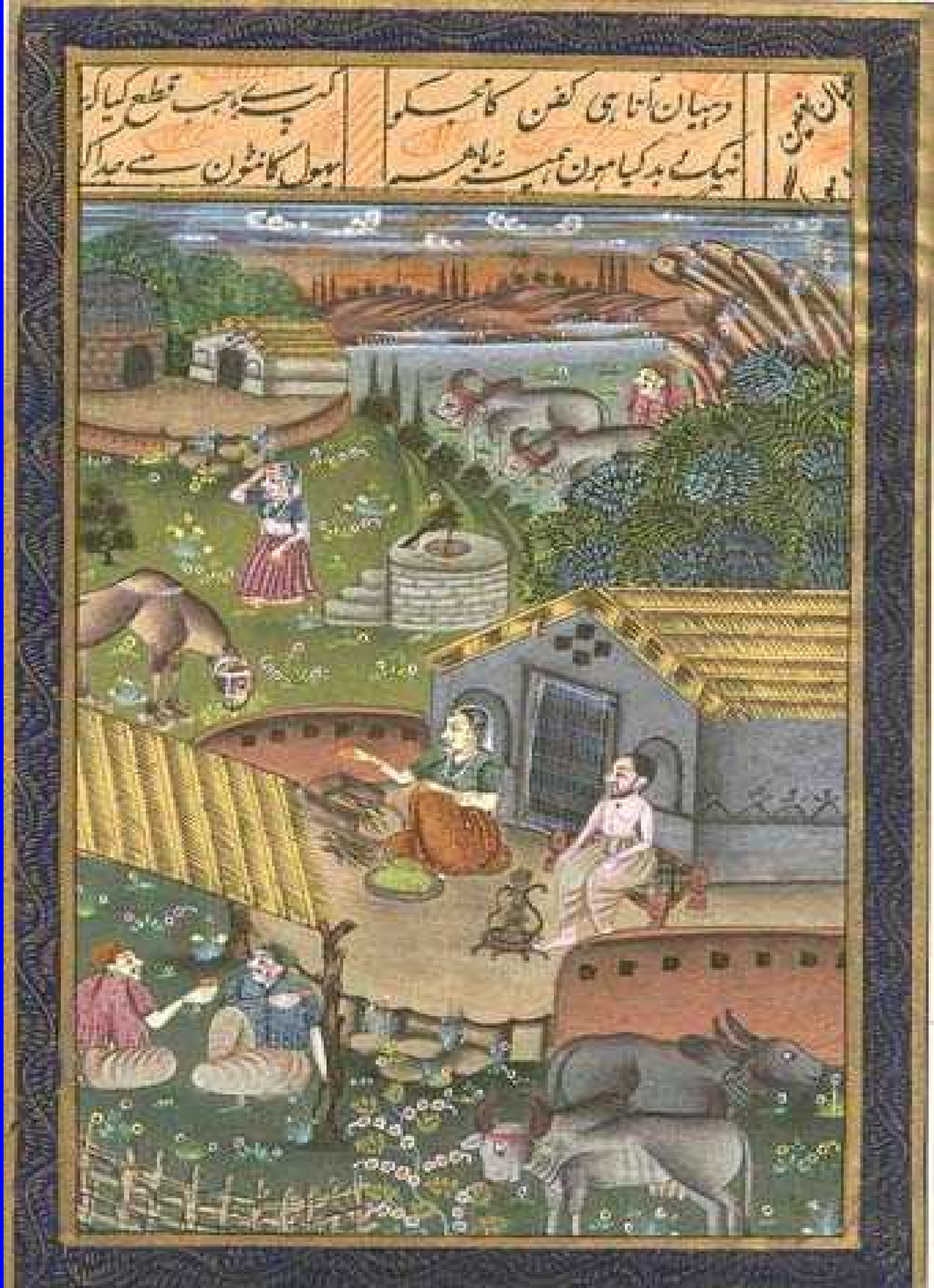
- Worst thing to do is stick burning stuff in your mouth – 5+ million premature deaths
- Next worse is burning in your house – 2 million deaths
- Next worse is having someone else nearby sticking in their mouth – 400k deaths
- Even bad to have on your planet – 2+ million deaths
- Chimneys do not help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

Wood

- “The fuel the heats you twice” - Thoreau
  - Once when you chop it
  - Once again when you burn it
- But actually through the smoke it heats you four times
  - Also the fever from the pneumonia
  - And the global warming it generates
- Get rid of incomplete combustion, however, and you eliminate the second two

Many thanks

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



The David Bates Memorial Lecture

- **David Bates,** UBC, *“Ozone, 42 Years Later”* (2006)
- **David Wegman**, UMASS-Lowell, *"Aging and Globalization from an OH Perspective”* (2007)
- **Moira Chan-Yeung**, UBC/University of Hong Kong, *"Western red cedar asthma”* (2008)
- **Trevor Ogden**, Editor in Chief, Annals of Occupational Hygiene *“Strategy for compliance testing with exposure limits”(*2009)
- **Marc Schenker**, UC-Davis *“Respiratory disease in agriculture workers”* (2010)
- **C Arden Pope III**, BYU “Exploring the Human Health Effects of Air Pollution: Was David Bates on the Right Path?” (2011)