Recent Health Effects Results from Guatemala: Implications for the Stove Community

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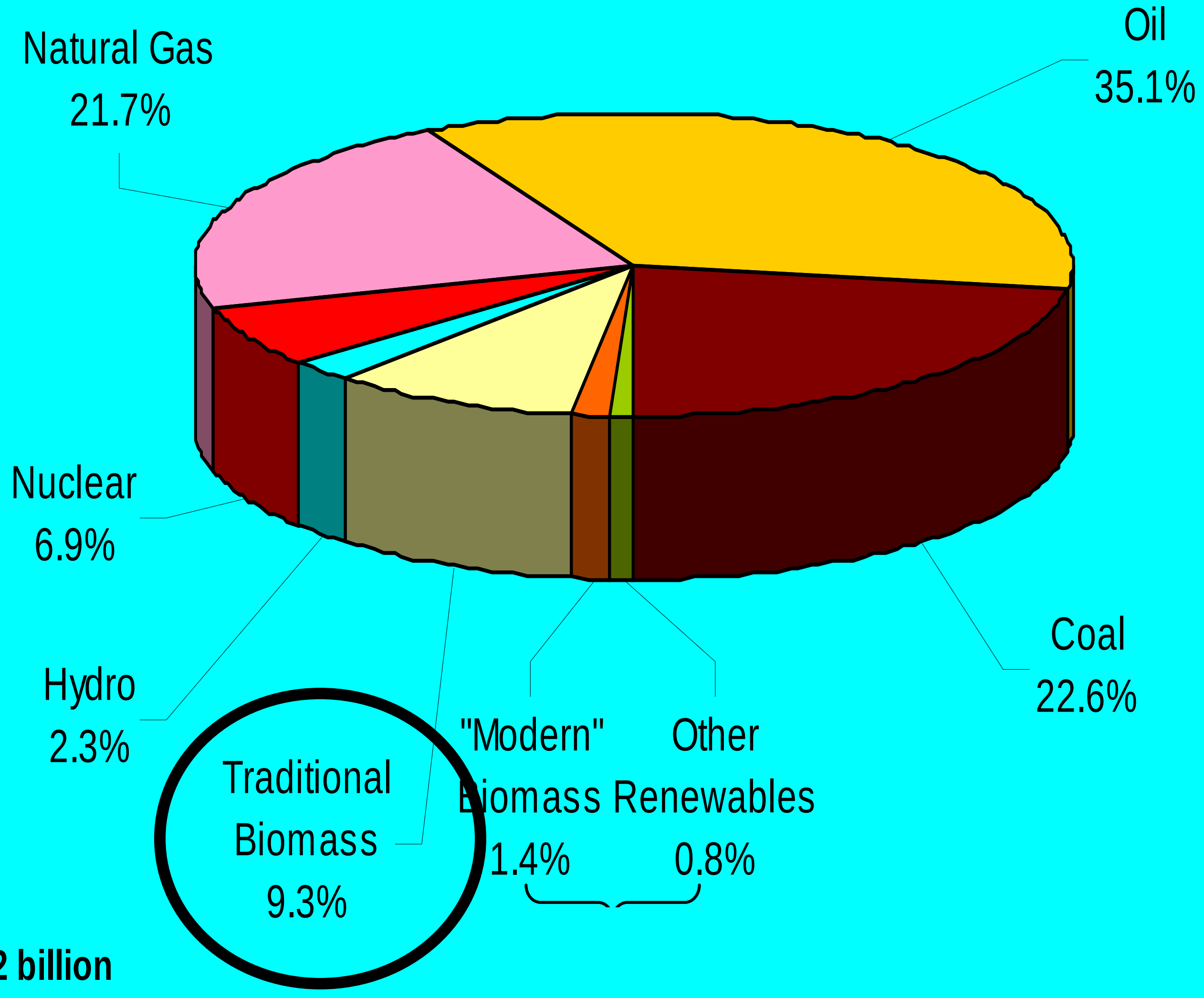
PCIA Forum, Kampala
March 28, 2009

Household Solid Fuel Burning

- Why solid fuel use can be a hazard
- Summary of current risk estimates for child pneumonia
- Results from the first randomized trial – RESPIRE in the Guatemalan Highlands
- M&E updates
- Implications for stove technology and dissemination

World Energy – 2001



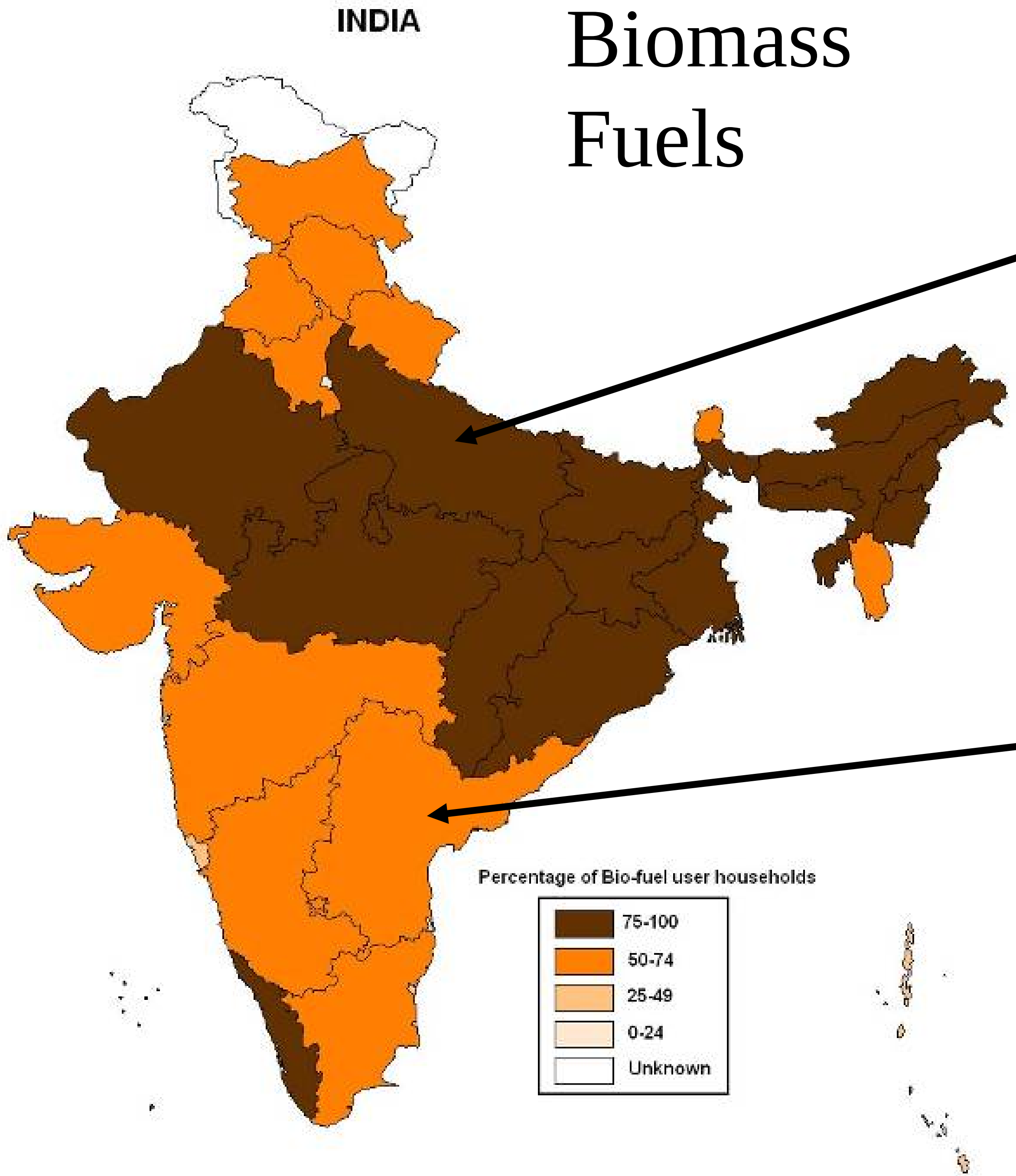
Population: 6.102 billion

Total energy use: 10.2 Gtoe

Per capita energy consumption: 1.67 toe

World Energy Assessment, 2004

Biomass Fuels



More than 75% of households

50-74% of households

2000 Census

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.

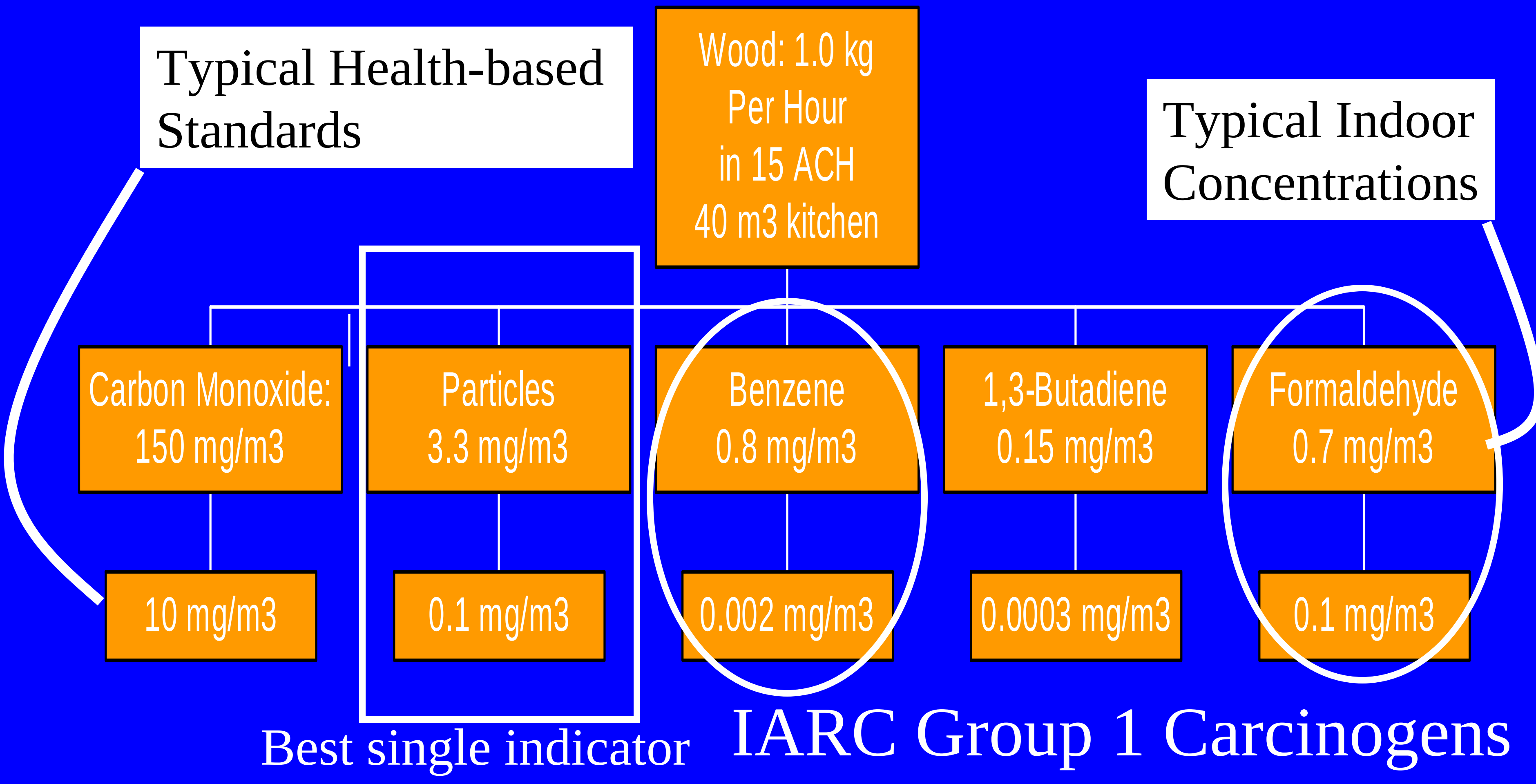
Source: Smith, et al., 2000

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

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



Location	Region	Number of households	Range (24 hour average of PM 10)	Mean (µg/m3) (24 hr average of Kitchen & Living Concentrations of PM10)	Other Determinants
Tamil Nadu	South	4[illegible]	[illegible]	223	Fuel/ Kitchen/Stove
Andhra Pradesh	South	3[illegible]	[illegible]	485	Fuel/ Kitchen
Karnataka	South	3[illegible]	[illegible]	898	Fuel/ Stove
Madhya Pradesh	West/Central	7[illegible]	[illegible]	690	Fuel/ Kitchen
Gujarat	West	6[illegible]	[illegible]	780	Fuel/ Kitchen
Goa	West	1[illegible]	[illegible]	635	Fuel/ Kitchen
West Bengal	East/North East	9[illegible]	[illegible]	795	Fuel/ Kitchen
Haryana	North	1[illegible]	[illegible]	850	Fuel/ Kitchen
Uttaranchal	North/Mountain	76	270-2240	620	Fuel/ Kitchen

WHO Global Air Quality Guideline for Indoor/Outdoor particle Levels

20 µg/m3

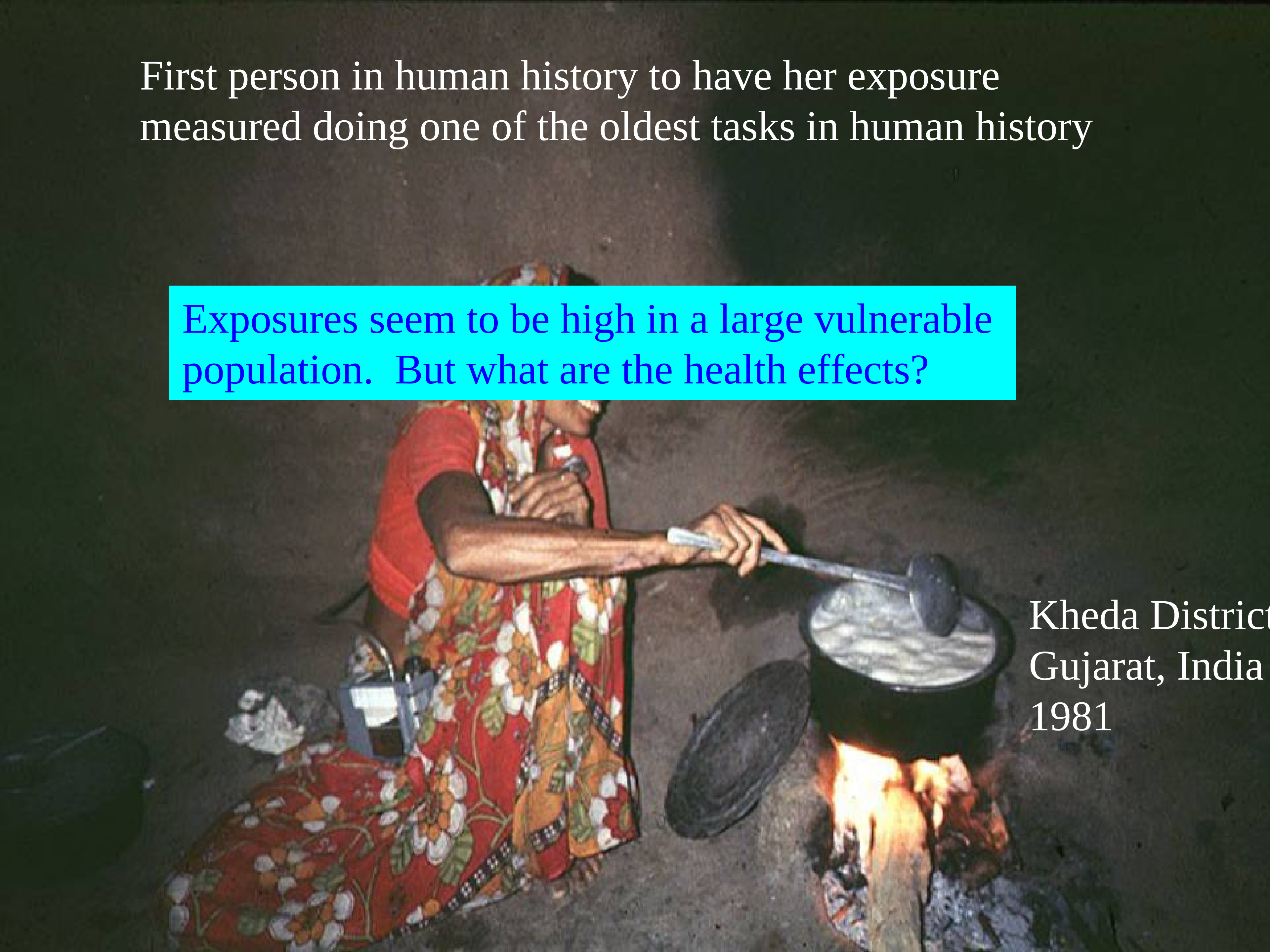
Absolutely no population even even poorest countries should be exposure to more than

70 µg/3

Data complied by SRU, Chennai

First person in human history to have her exposure measured doing one of the oldest tasks in human history

Exposures seem to be high in a large vulnerable population. But what are the health effects?



Kheda Distric
Gujarat, India
1981

How Much Global Ill-Health can be Attributed to Household Indoor Air Pollution?

- What do we mean by “ill-health?”
- What do we mean by “attributed?”
- What do we mean by “indoor air pollution”

What do we mean by ill-health?

- Lost life-years, which accounts for age of premature death and duration of illness
- DALYs = Disability adjusted life years lost

What do we mean by "indoor air pollution"

- Too few measurements worldwide to determine exposures by measurements
- Can use solid fuel use as a proxy as widespread surveys available
- Makes physical sense because of larger pollutant emissions
- There is a growing epidemiologic literature showing health effects

The Energy Ladder: Relative Pollutant Emissions Per Meal

India Data

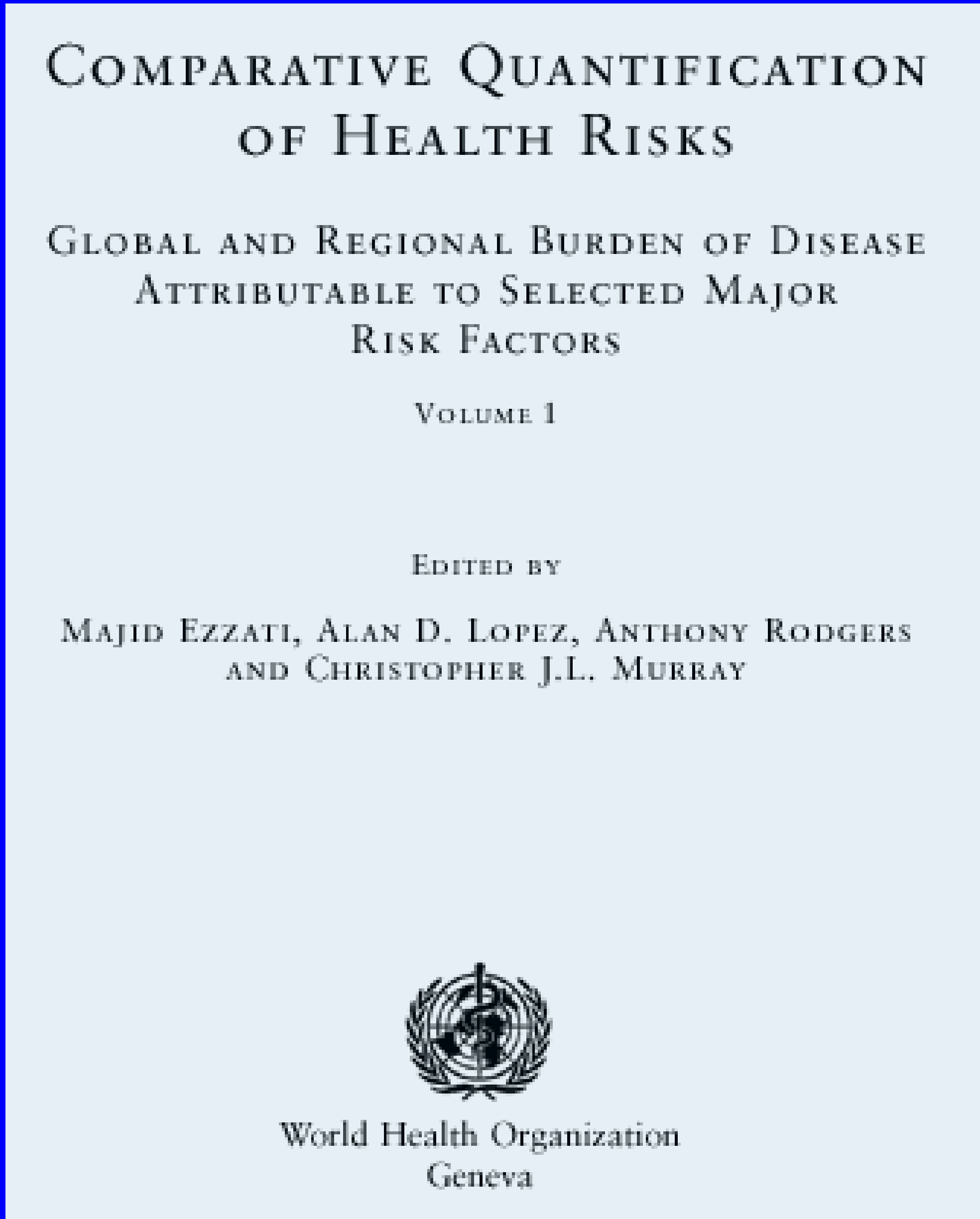
	Biogas	LPG	Kerosene	Wood	Roots	Crop Residues	Dung
CO	0.1	1.0	3	19	22	60	64
Hydrocarbons	0.3	1.0	4.2	17	18	32	115
PM	2.5	1.0	1.3	26	30	124	63

Smith, et al., 2005

CO *Hydrocarbons* *PM*

Attributable Risk?

- The amount of ill-health that would not exist today if the exposure to the risk factor had not occurred in the past.



COMPARATIVE QUANTIFICATION OF HEALTH RISKS

GLOBAL AND REGIONAL BURDEN OF DISEASE ATTRIBUTABLE TO SELECTED MAJOR RISK FACTORS

VOLUME 1

EDITED BY

MAJID EZZATI, ALAN D. LOPEZ, ANTHONY RODGERS AND CHRISTOPHER J.L. MURRAY

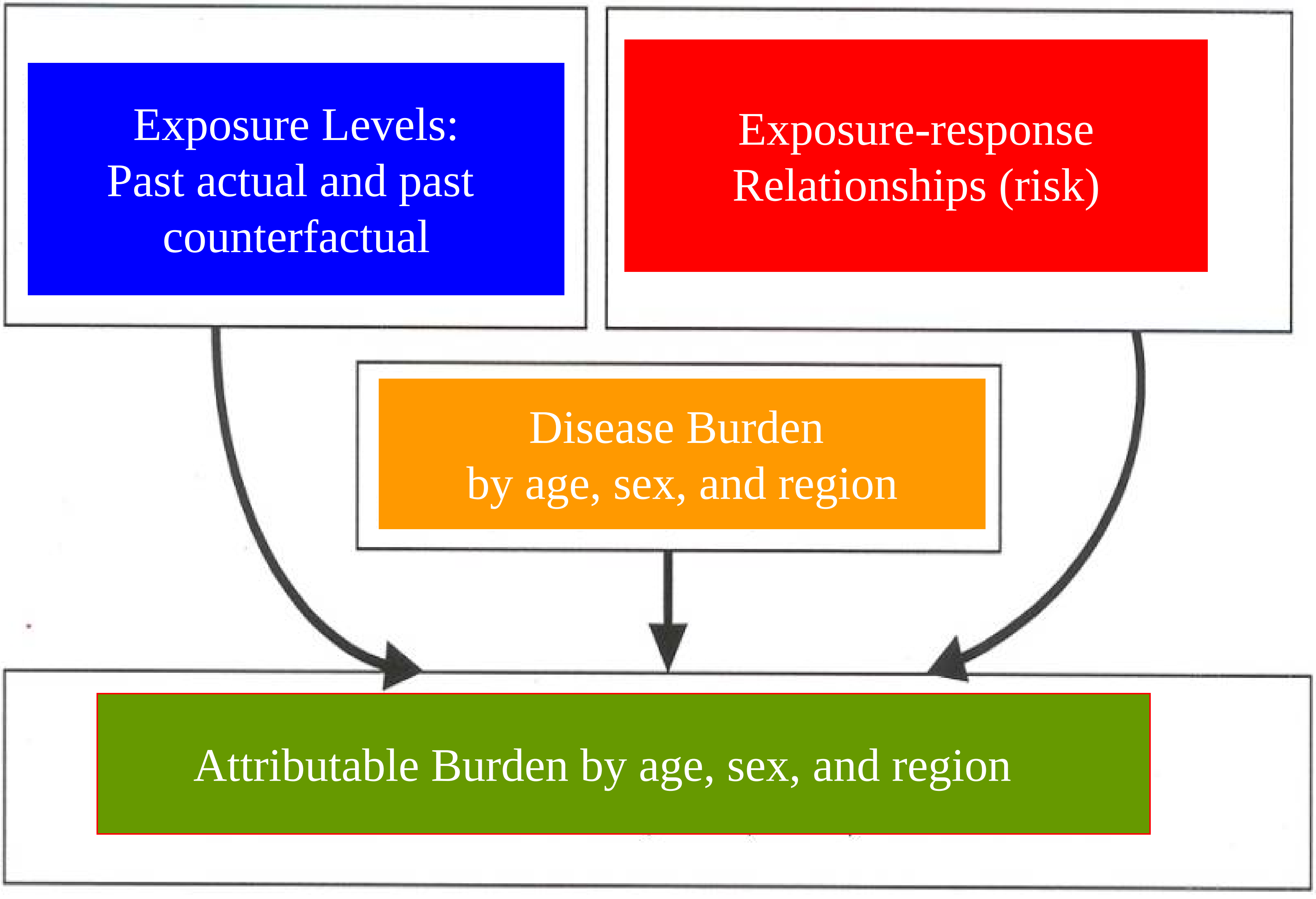
World Health Organization
Geneva

Published in late 2004,
2 vols, ~2500 pp

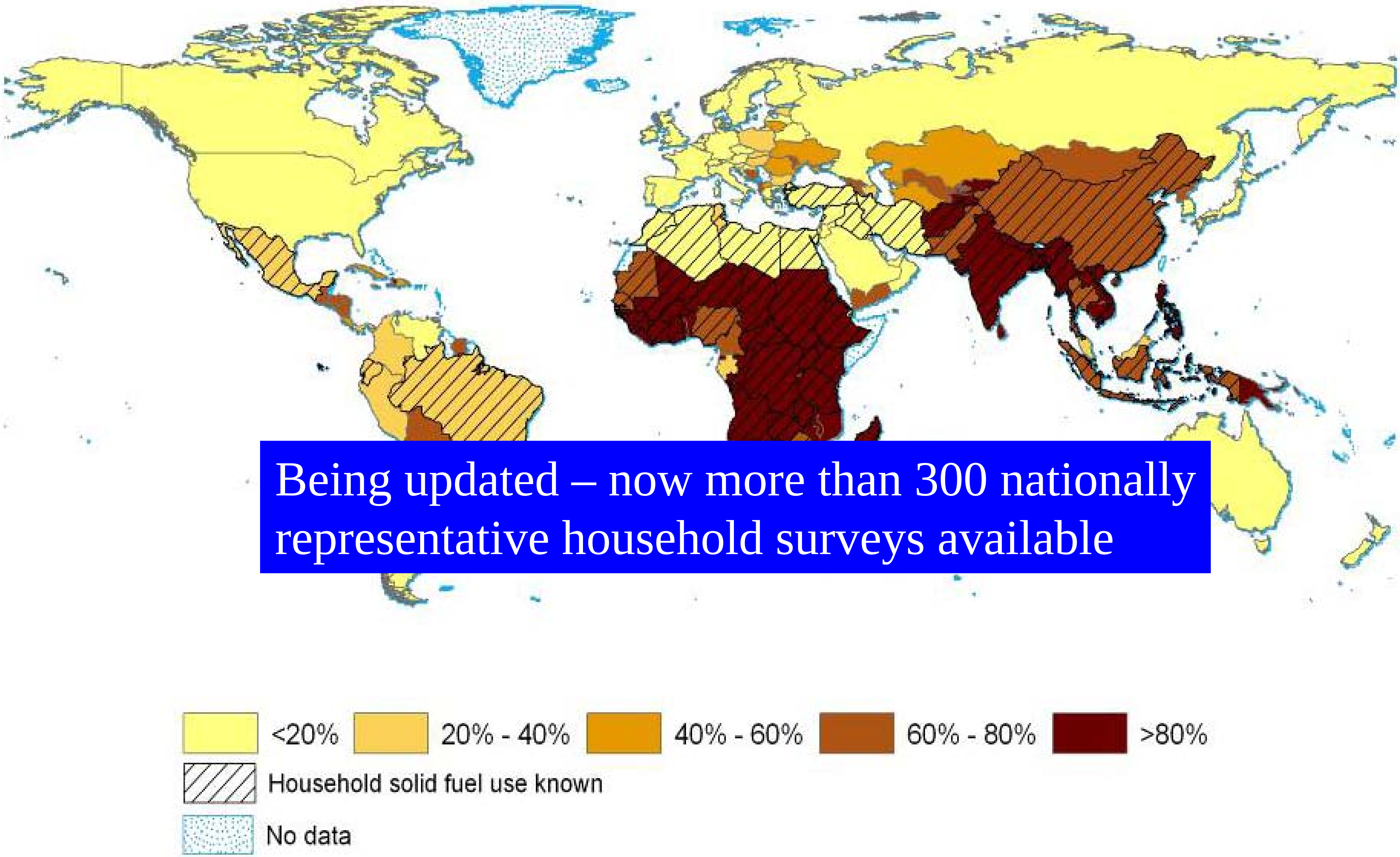
Available on World Health Organization website

http://www.who.int/publications/cra/en/

Comparative Risk Assessment Method



National Household Solid Fuel Use, 2000



Being updated – now more than 300 nationally representative household surveys available

Diseases for which we have studies showing links to household solid fuel use

ALRI/ Pneumonia (meningitis)

Low birth weight & stillbirth

Asthma?

Early infant Death?

Cognitive Effects (lower IQ)?

Birth defects?; cleft

Chronic obstructive lung disease

Interstitial lung disease

Cancer (lung, NP, cervical, aero-digestive)

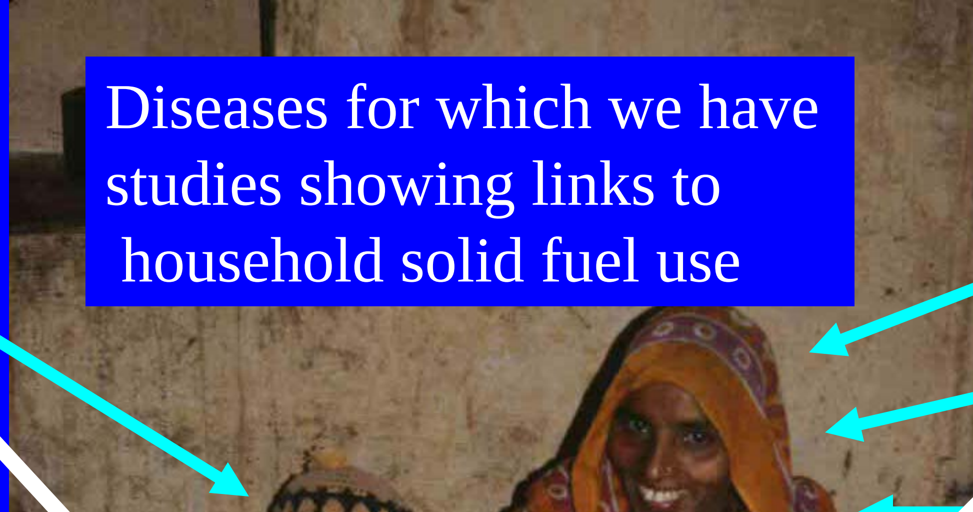
Blindness (cataracts, trachoma)

Tuberculosis

Heart disease?

Fire-related deaths and burns

ALRI/
Pneumonia
(meningitis)



Diseases for which we have studies showing links to household solid fuel use

Chronic obstructive lung disease

Only two qualified with sufficient evidence to be included in the original WHO Comparative Risk Assessment – 2004

More to be added in the update, slated for 2010

The Lancet, March 2, 2009

Fire-related deaths in India in 2001: a retrospective analysis of data

106,000 deaths in women/y

Prachi Sanghavi, Kavi Bhalla, Veena Das

Summary

Background Hospital-based studies have suggested that fire-related deaths might be a neglected public-health issue in India. However, no national estimates of these deaths exist and the only numbers reported in published literature come from the Indian police. We combined multiple health datasets to assess the extent of the problem.

Methods We computed age–sex-specific fire-related mortality fractions nationally using a death registration system based on medically certified causes of death in urban areas and a verbal autopsy based sample survey for rural populations. We combined these data with all-cause mortality estimates based on the sample registration system and the population census. We adjusted for ill-defined injury categories that might contain misclassified fire-related deaths, and estimated the proportion of suicides due to self-immolation when deaths were reported by external causes.

Findings We estimated over 163 000 fire-related deaths in 2001 in India, which is about 2% of all deaths. This number was six times that reported by police. About 106 000 of these deaths occurred in women, mostly between 15 and 34 years of age. This age–sex pattern was consistent across multiple local studies, and the average ratio of fire-related deaths of young women to young men was 3:1.

Interpretation The high frequency of fire-related deaths in young women suggests that these deaths share common causes, including kitchen accidents, self-immolation, and different forms of domestic violence. Identification of populations at risk and description of structural determinants from existing data sources are urgently needed so that interventions can be rapidly implemented.

Funding None.

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Acute lower respiratory infections (ALRI)

Chief cause of death among the world's children (>2 million per year). Thus, it is the chief global cause of lost healthy life years.

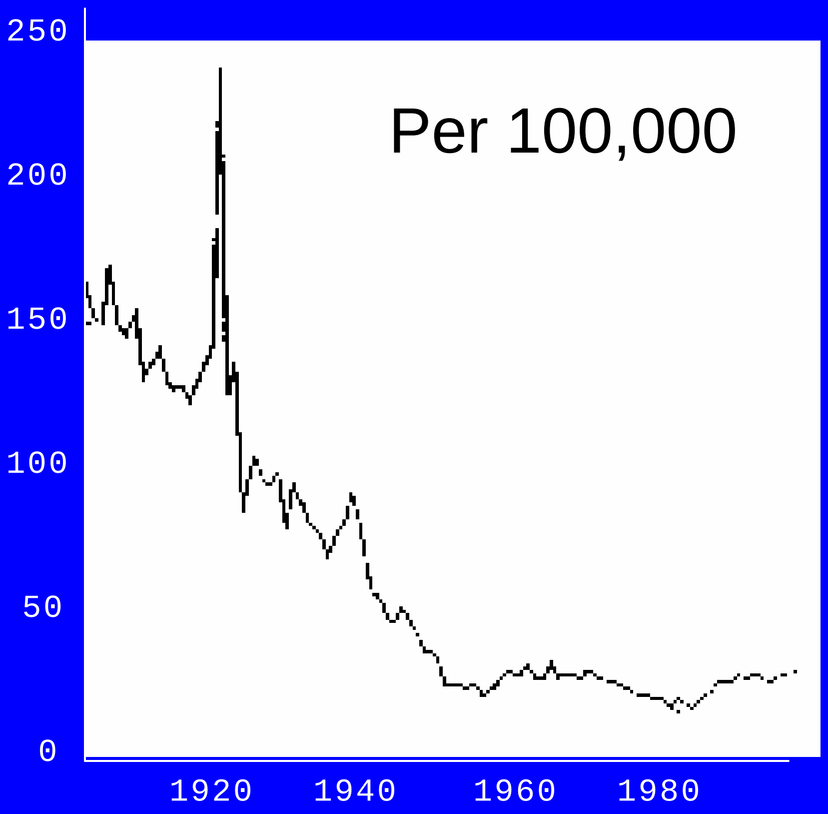
Child mortality occurs almost entirely in developing countries, and as pneumonia.

Well-accepted risk factors (malnutrition, micro-nutrient deficiencies, other diseases, crowding, chilling) do not account for its scale.

Pneumonia Deaths in the United States

Not so long ago pneumonia was chief cause of death in developed countries

SOURCE: National Center for Health Statistics, 2004. No age adjustment



ALRI associated with use of solid fuels: analysis of ~10 observational studies

Subgroup analyses	Odds ratio (95% CI)
All studies	2.3 (1.9-2.7)
Use of solid fuel	2.0 (1.4-2.8)
Duration of time child spent near the cooking fire	2.3 (1.8-2.9)
Studies adjusting for nutritional status	3.1 (1.8-5.3)
Studies not adjusting for nutritonal status	2.2 (2.0-3.0)
Children aged <2 years old	2.5 (2.0-3.0)
Children aged <5 years old	1.8 (1.3-2.5)

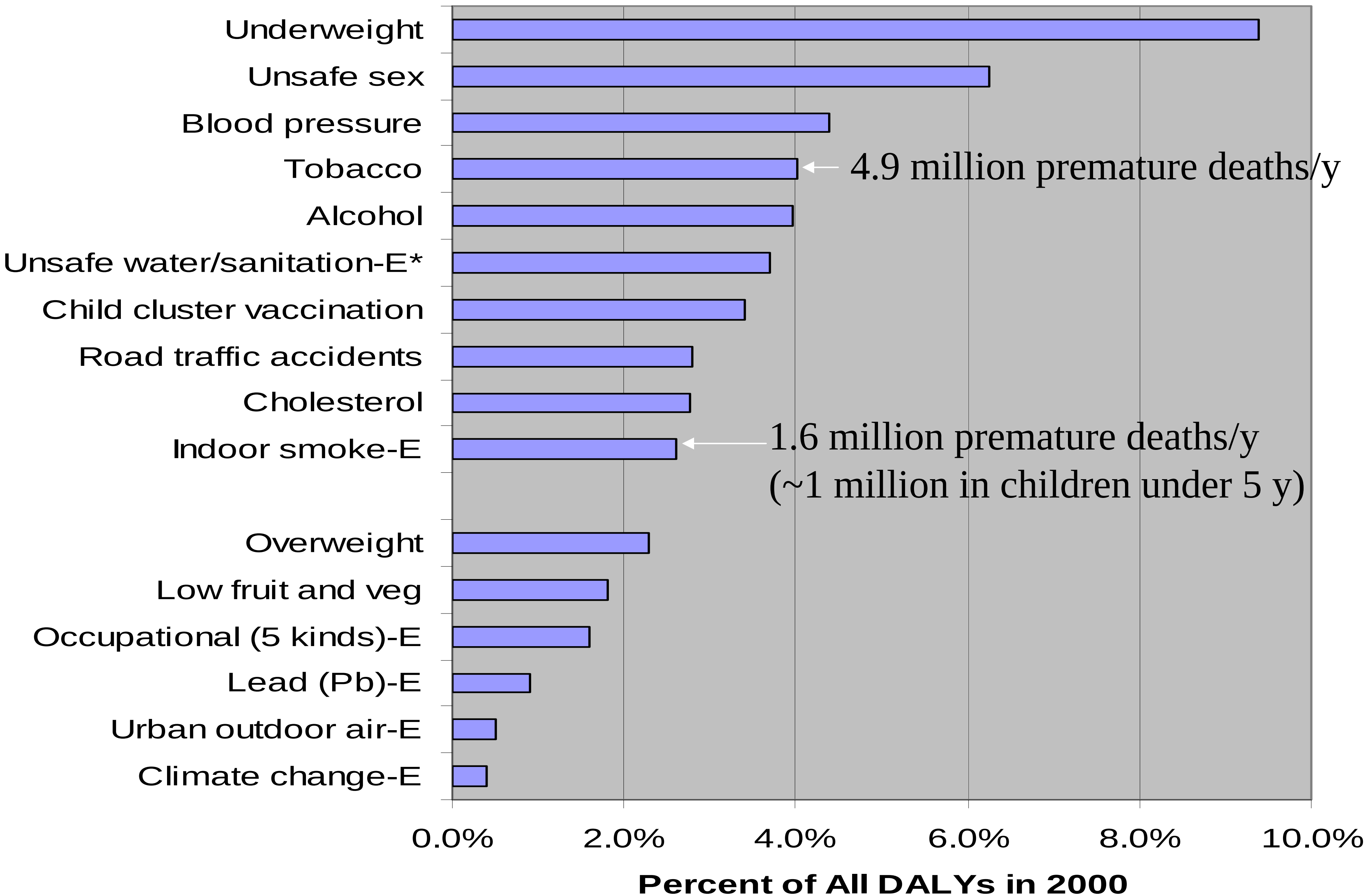
Smith et al in WHO, Comparative quantification of health risks, 2004

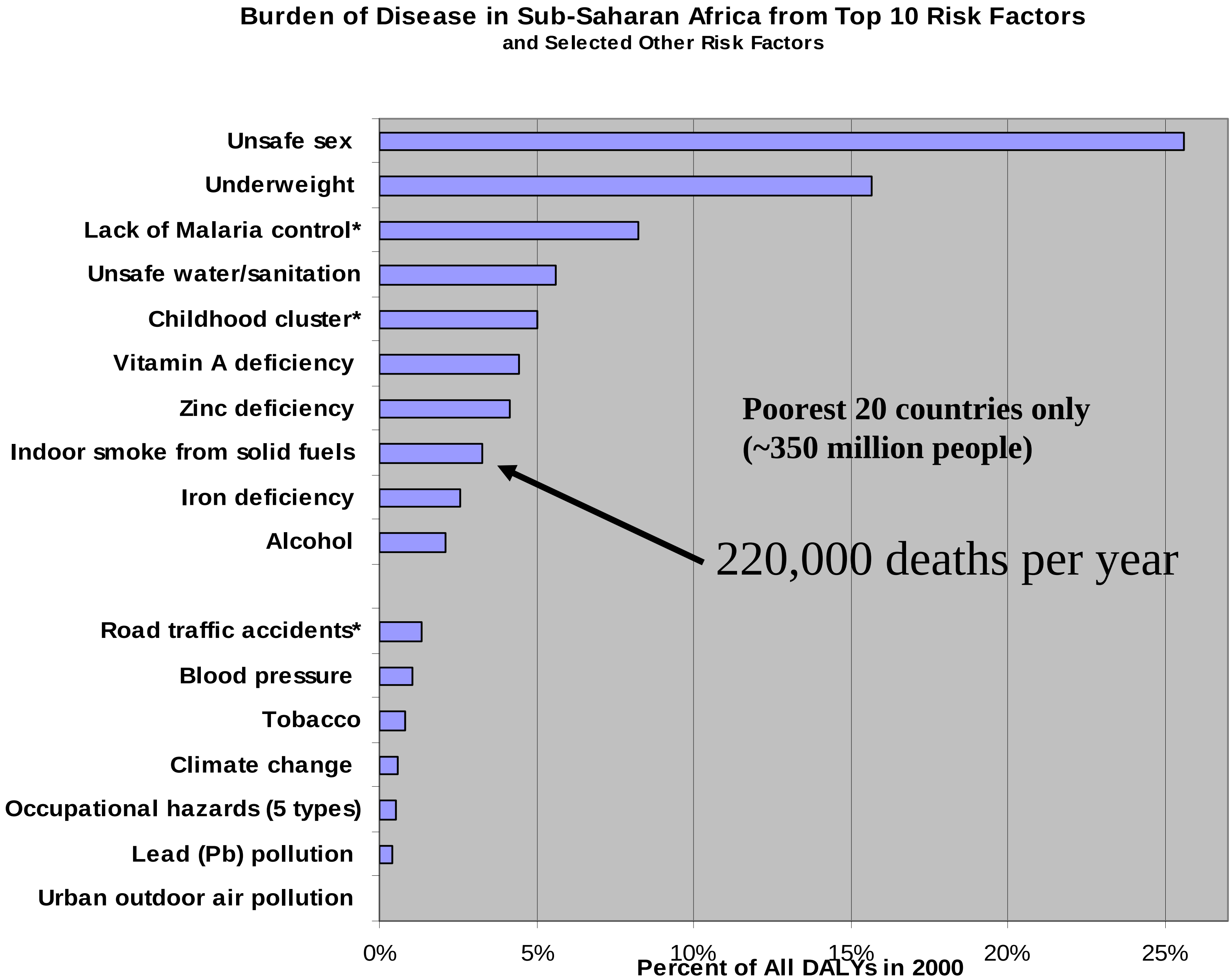
Consistent with

- Controlled animal and human exposures showing effects on respiratory immune system
- Dozens of studies of the effect of environmental tobacco smoke exposures in children
- A few studies of outdoor air pollution

Global Burden of Disease from Top 10 Risk Factors

plus selected other risk factors





In Smith et al., 2005. Derived from WHO data

Problems with all Previous ALRI and IAP Studies

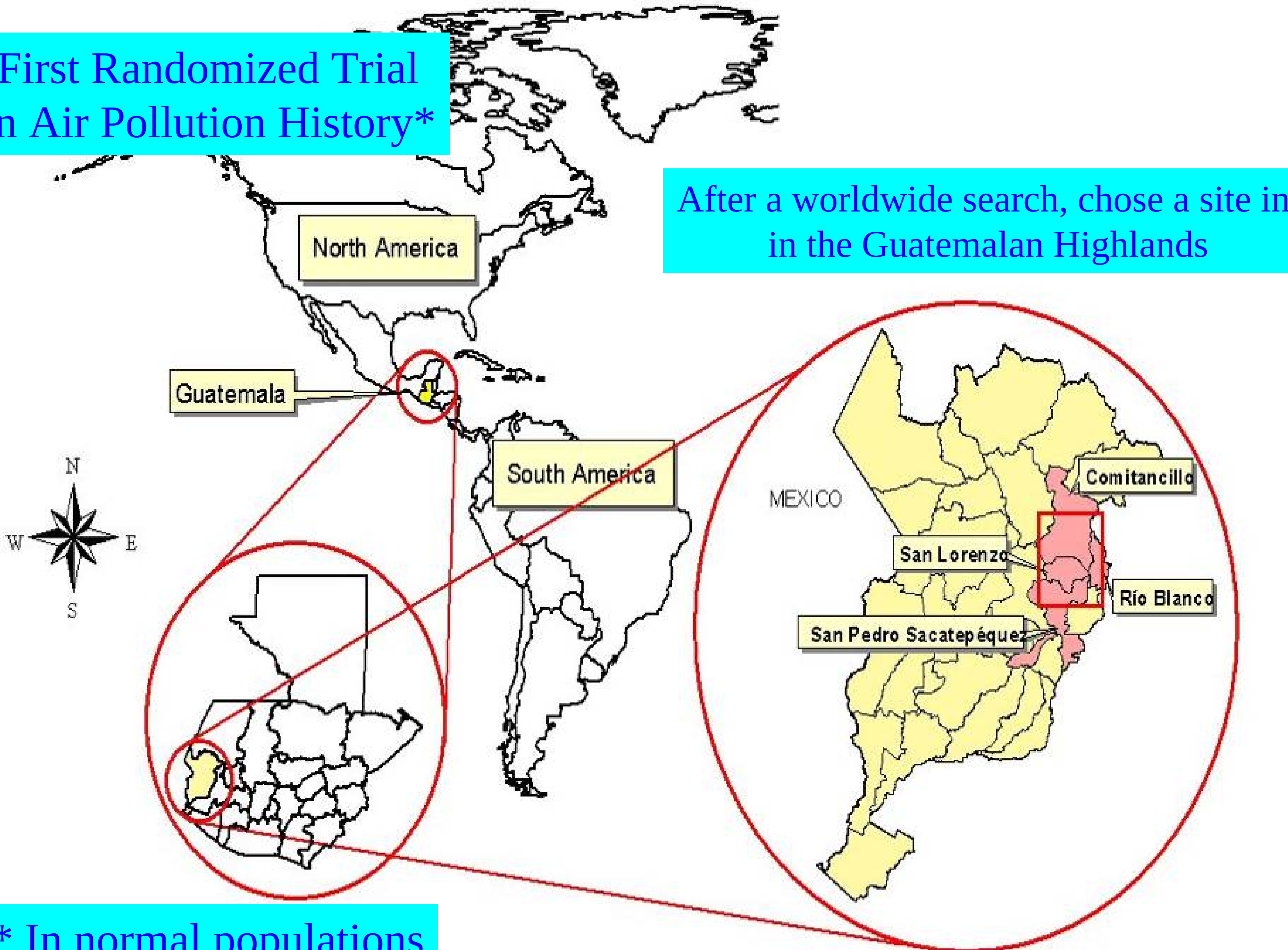
- Studies were all observational and thus not able to be sure the effect was not due just to poverty and not air pollution.
- Too much confusion with upper respiratory infections
- Little or no exposure assessment.
- Solution is a
  - Randomized control trial (RCT) in which half households receive improved stove on a random basis at the start, other keep open fires until end
  - Much better diagnosis of disease
  - Full exposure assessment

History of a RCT

- ~1980: Early studies of health effects in Nepal and elsewhere
- 1981: First measurements of pollution levels in India
- 1984: International meeting to decide on needed research
  - Chose randomized control 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
- 1996-1999: Unfunded proposals
- 2001: NIEHS funding secured
- 2002-2005: Fieldwork completed
- 2007: First results published
- 23+ years from deciding to conduct RCT to results!

First Randomized Trial In Air Pollution History*

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

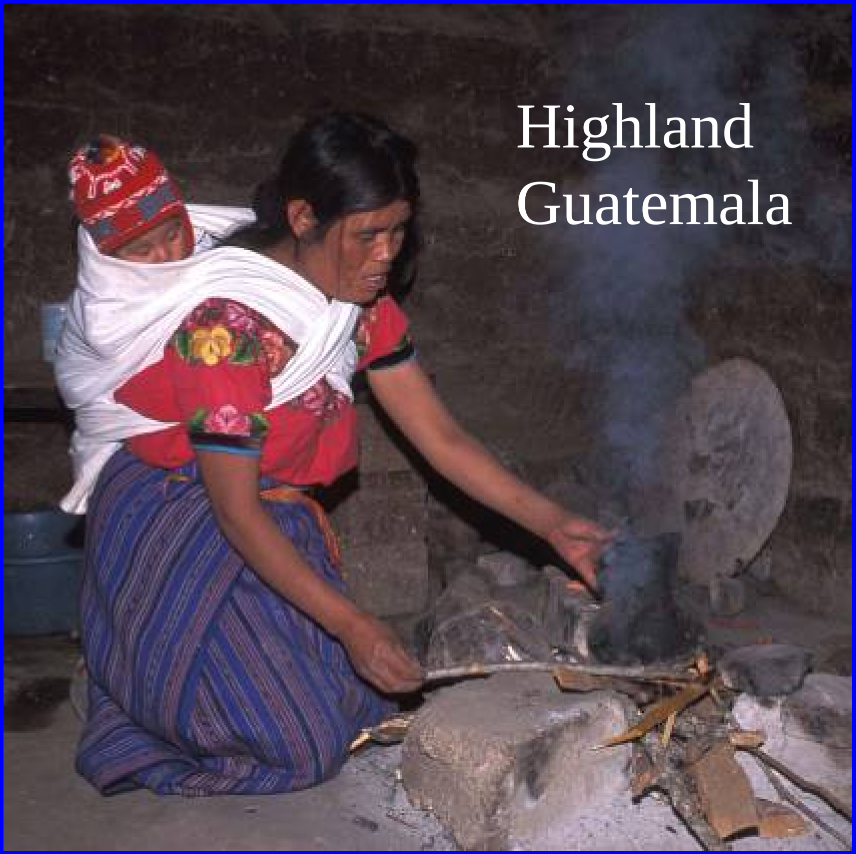


* In normal populations

Setting

- Rural highlands of San Marcos, western Guatemala
- Population nearly all indigenous Mayan Indians
- Nearly all depend on wood for cooking and heating
- Traditional stove is the 3-stone fire – no venting to outside
- Very poor, high IMR, pneumonia, diarrhea and stunting common
- Poor health service uptake - culture, language, transport, time
- Intervention is a stove with chimney that is well-accepted by community

RESPIRE: (Randomized Exposure Study of Pollution Indoors and Respiratory Effects)



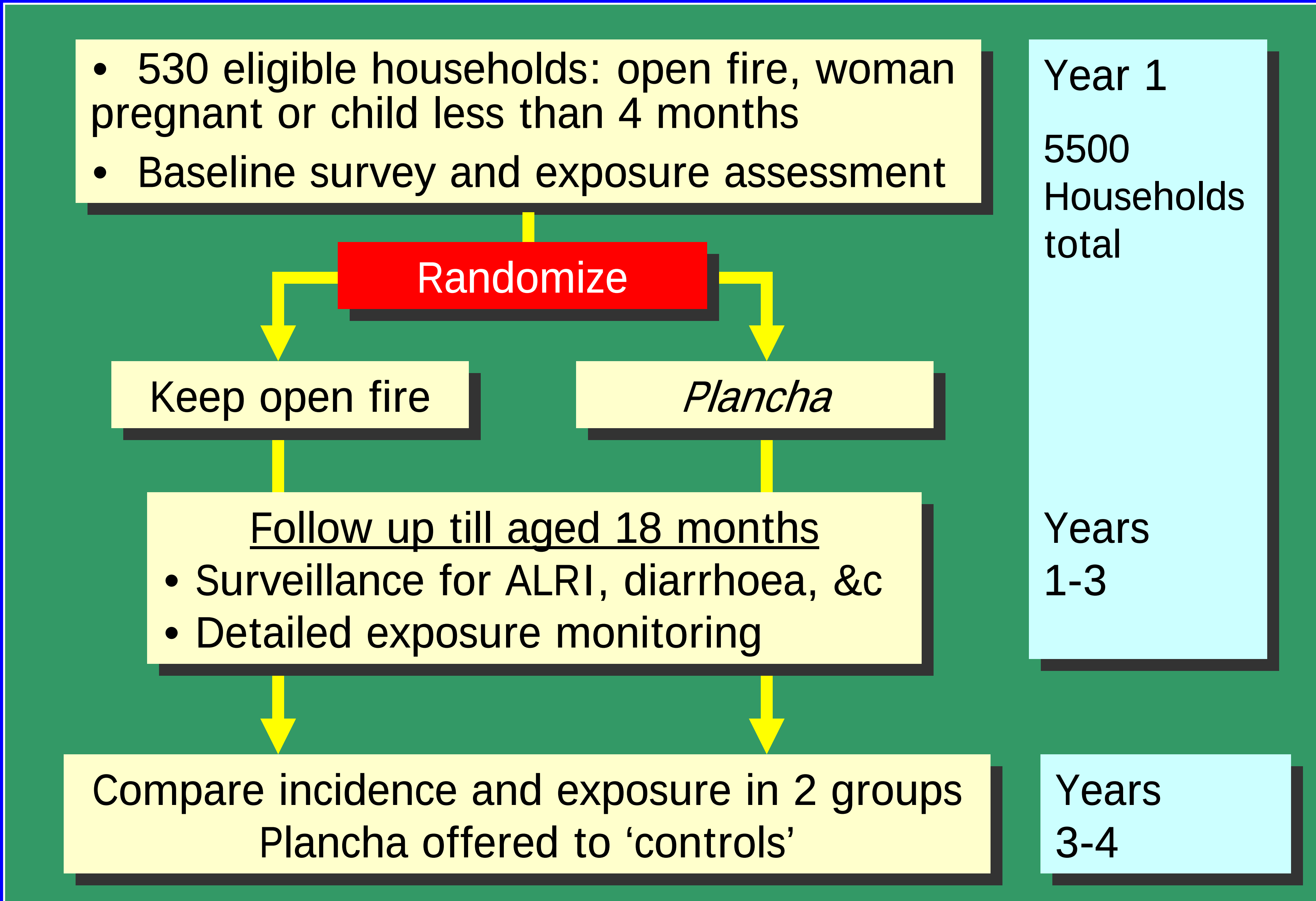
Traditional 3-stone open fire

Plancha chimney wood stove

RESPIRE Teams

- 25-35 fulltime field staff
  - 17-25 locally hired bilingual (Mam-Spanish) fieldworkers
  - Field manager
  - 2 field supervisors
  - Data manager
  - 2-3 physicians
  - Environment engineer for air pollution monitoring
  - 4-6 office/data entry staff
  - All Guatemalan
- Investigators and students in Berkeley, Guatemala, Liverpool, Boston, Geneva, and Bergen
- International **Data Safety Management Board** for ongoing protection of human subjects
- NIH and several other funders

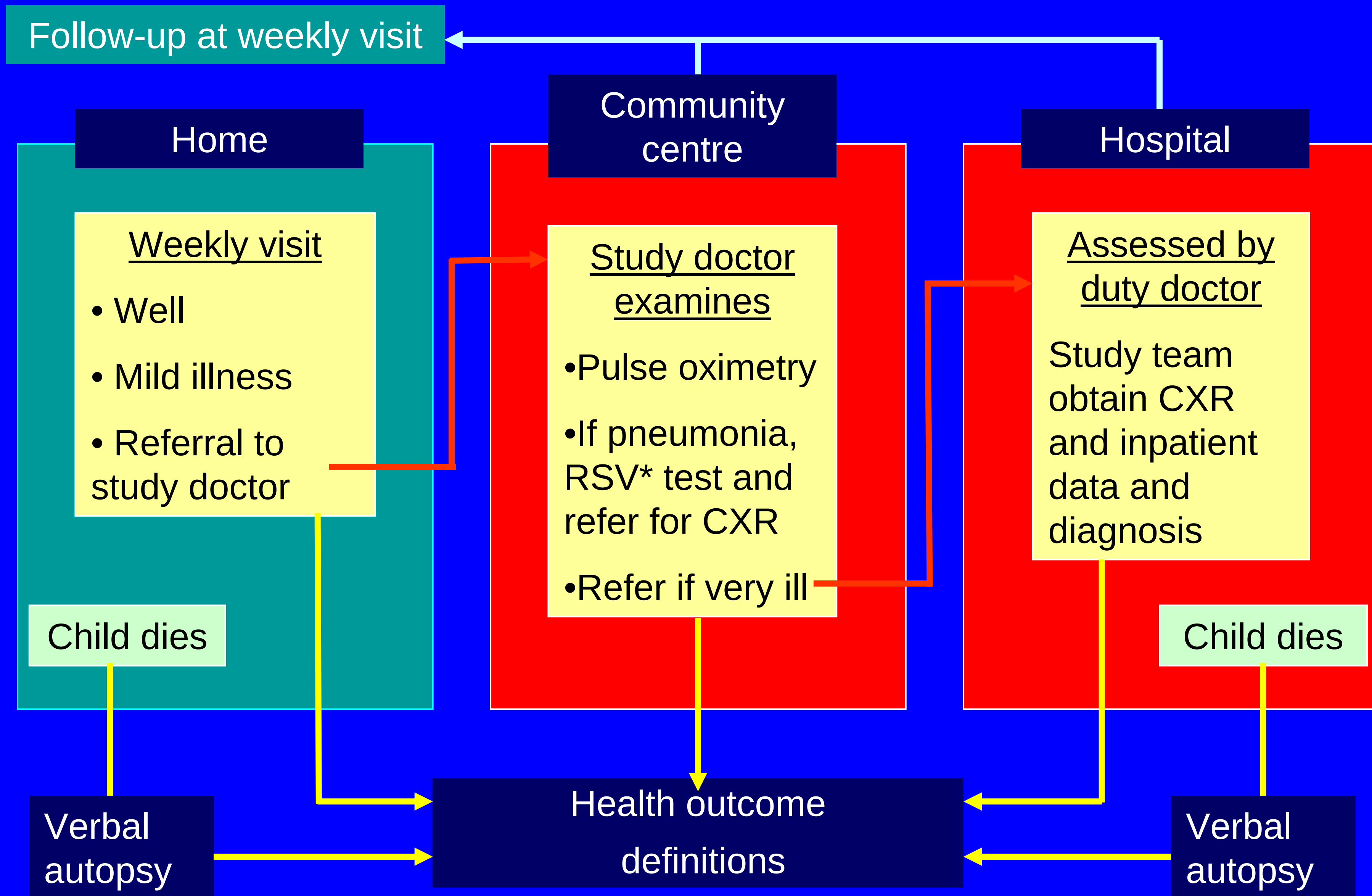
Overview of RESPIRE study design



Randomisation: balance of groups at baseline

Variable	Control	Intervention
Socio-demographic factors		
Mother's Age (years)	27.0	26.4
Pregnant at recruitment (%)	48.3	51.3
Own home (%)	92.8	94.1
Migrates part of year (%)	17.7	17.1
House structure		
Separate enclosed cooking area (%)	76.2	74.3
Completely open eaves (%)	42.7	40.6
Walls – adobe (mud) (%)	88.7	90.7
Roof – metal (%)	77.4	74.3
Floor – earth (%)	92.5	88.8
Leaks in roof (water) (%)	24.5	33.3
Electricity (%)	70.8	69.3
Other sources of smoke		
Other fire near house (%)	14.6	14.4
Smoking (tobacco) indoors (%)	26.8	20.4
Use traditional sauna bath (%)	84.5	87.8
Geographic		
Mean altitude (metres)	2613	2601

Overview of child health outcomes assessment



* Respiratory syncitial virus

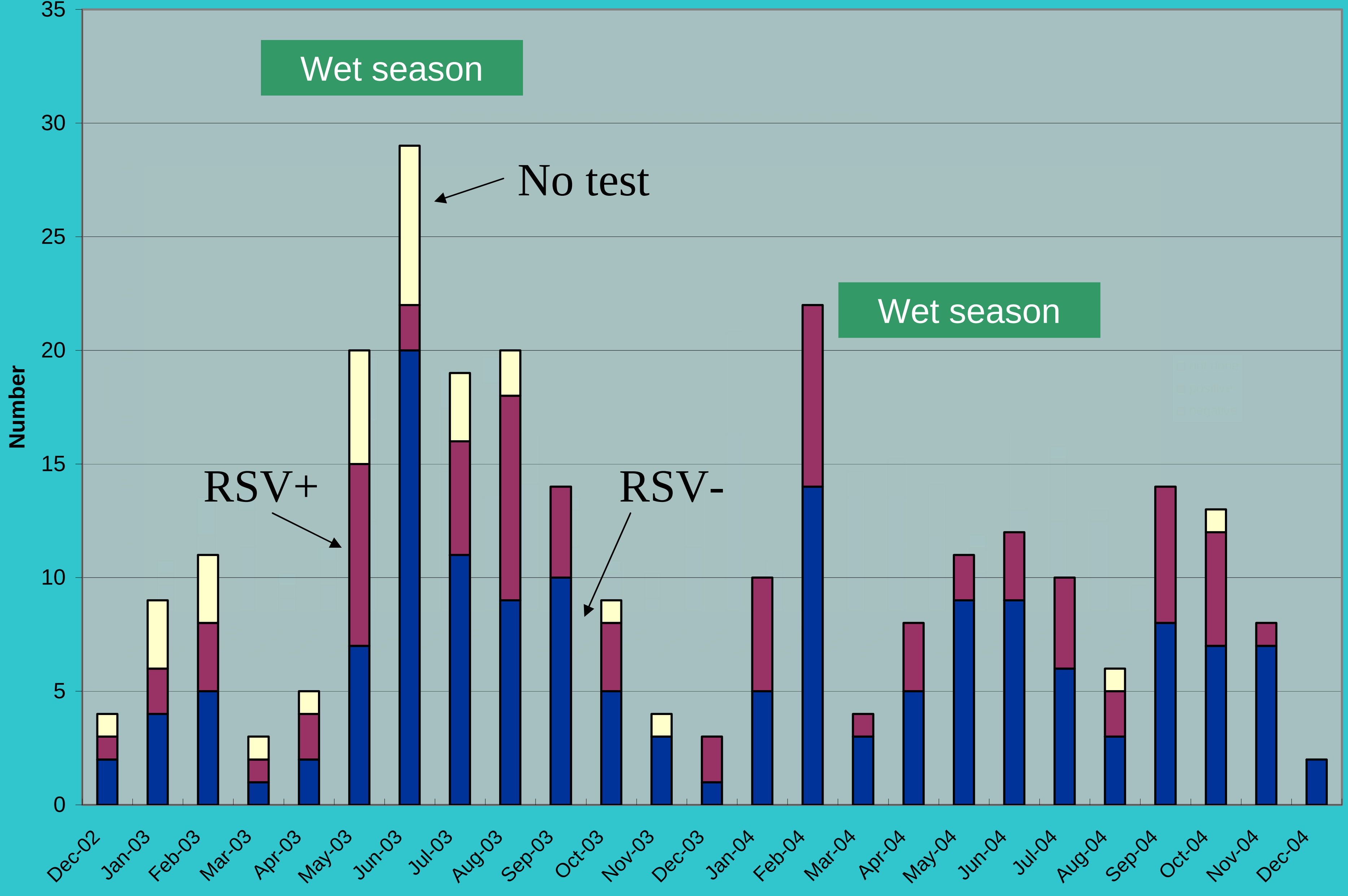
PHYSICIAN ASSESSMENT

- Clinical assessment is the key outcome
- Needed to standardise
- Six employed (four assessed 96.4% referrals)
- Use of agreed terms and signs
- Initial 'calibration' and ongoing ($\pm$ monthly) clinical sessions

PULSE OXIMETRY

- Non-invasive and well-accepted (99%)
- Measure of severity (of respiratory illness):
  - mortality up to x5 in hypoxaemic
- Well children (n=55)
  - Mean (SD) 93.2% (3.0)
  - Hypoxaemic defined as mean – 2SD = 87%
- Bogota (5d – 24mo) altitude 2640m, mean (SD) 93.3% (2.1)

Pneumonia by month and RSV status



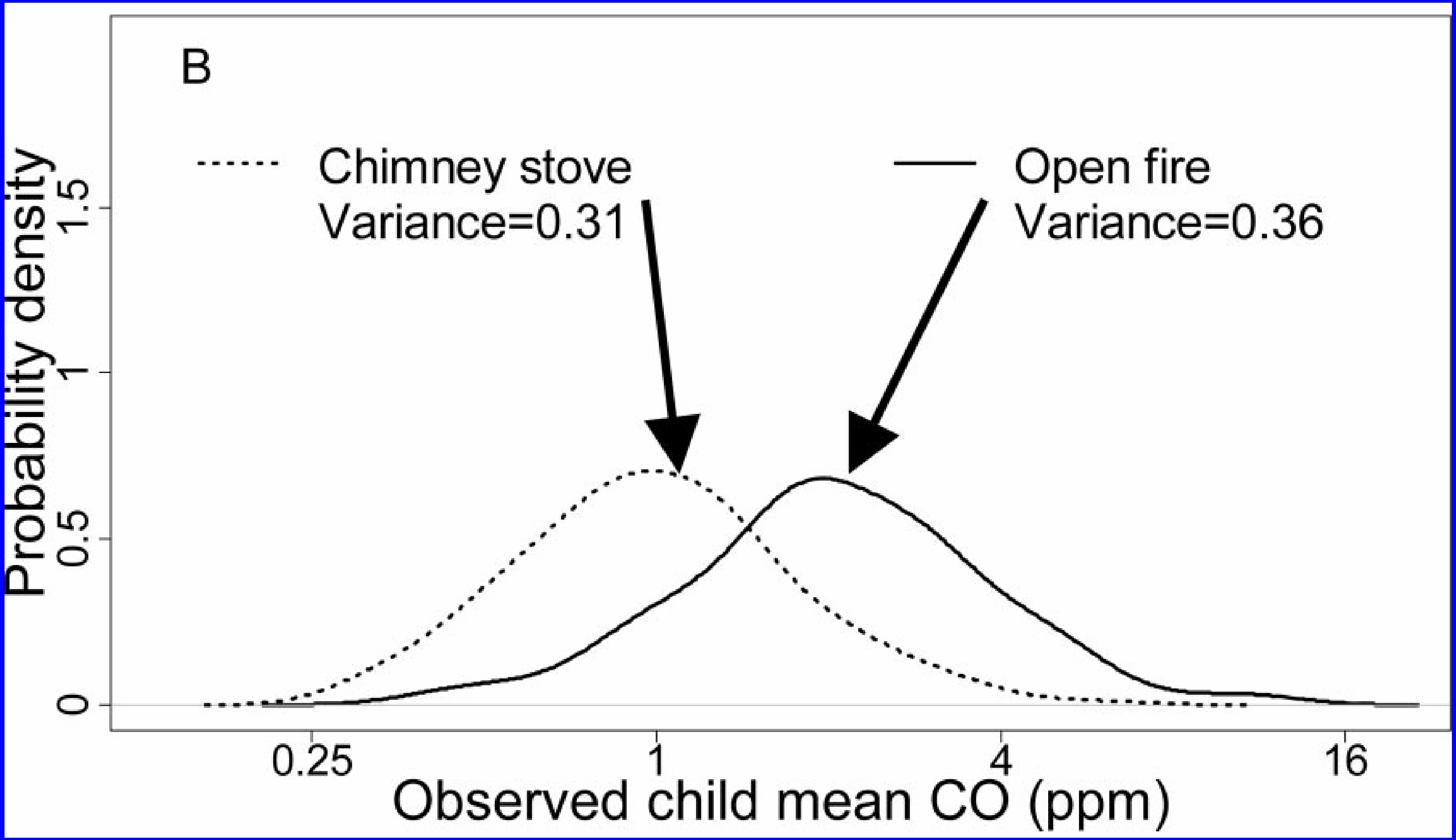
Unpublished results from RESPIRE have been removed

Watch the website below where they will be posted as soon as they are published.

http://ehs.sph.berkeley.edu/krsmith

Regrets/KR Smith


Tubito
Tubito



What a Well-Operating Chimney Does

McCracken, et al., 2009

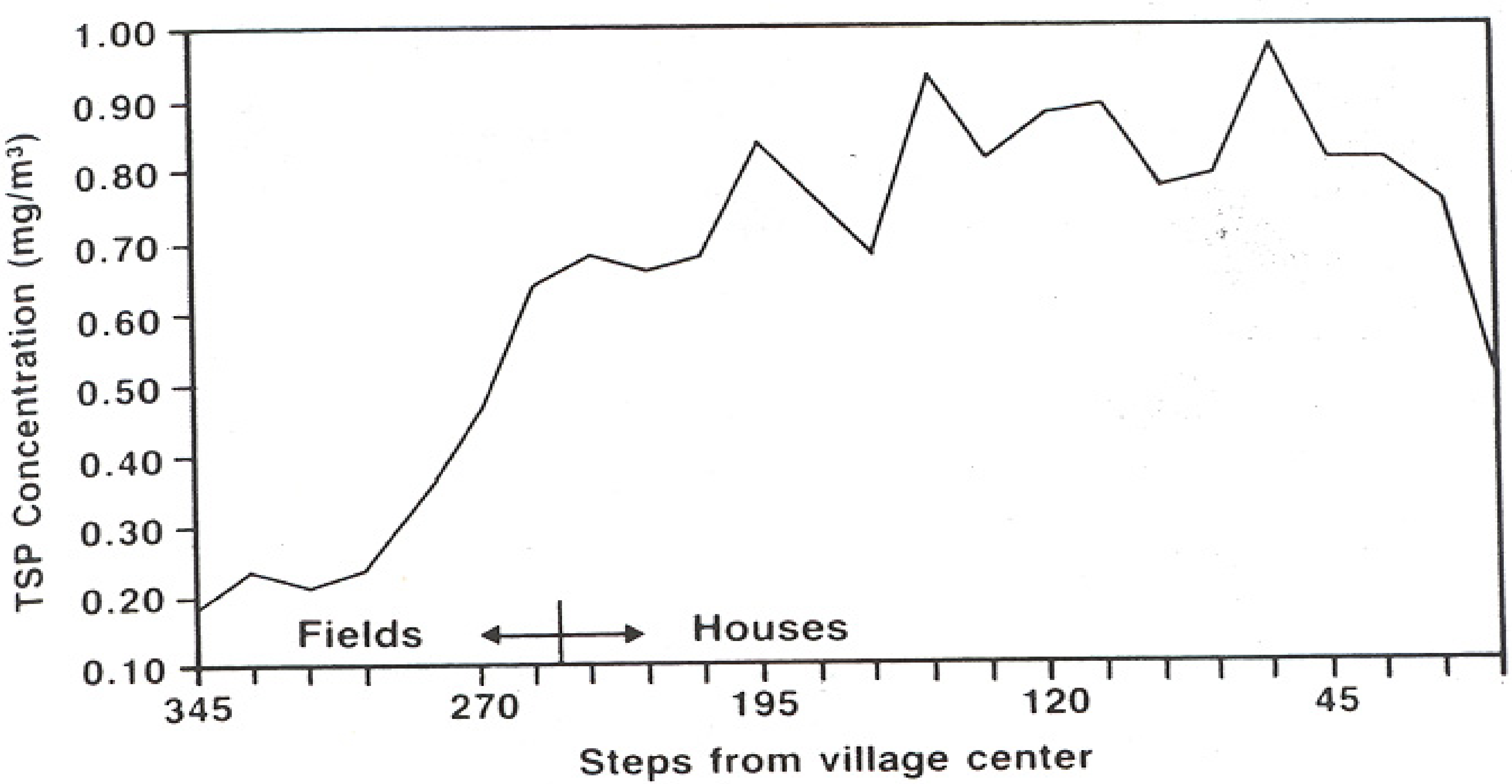
Effect of Plancha on PM2.5

Reasons that child personal exposures did not lower as much as kitchen levels:

- --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
- --Other burning around house not different

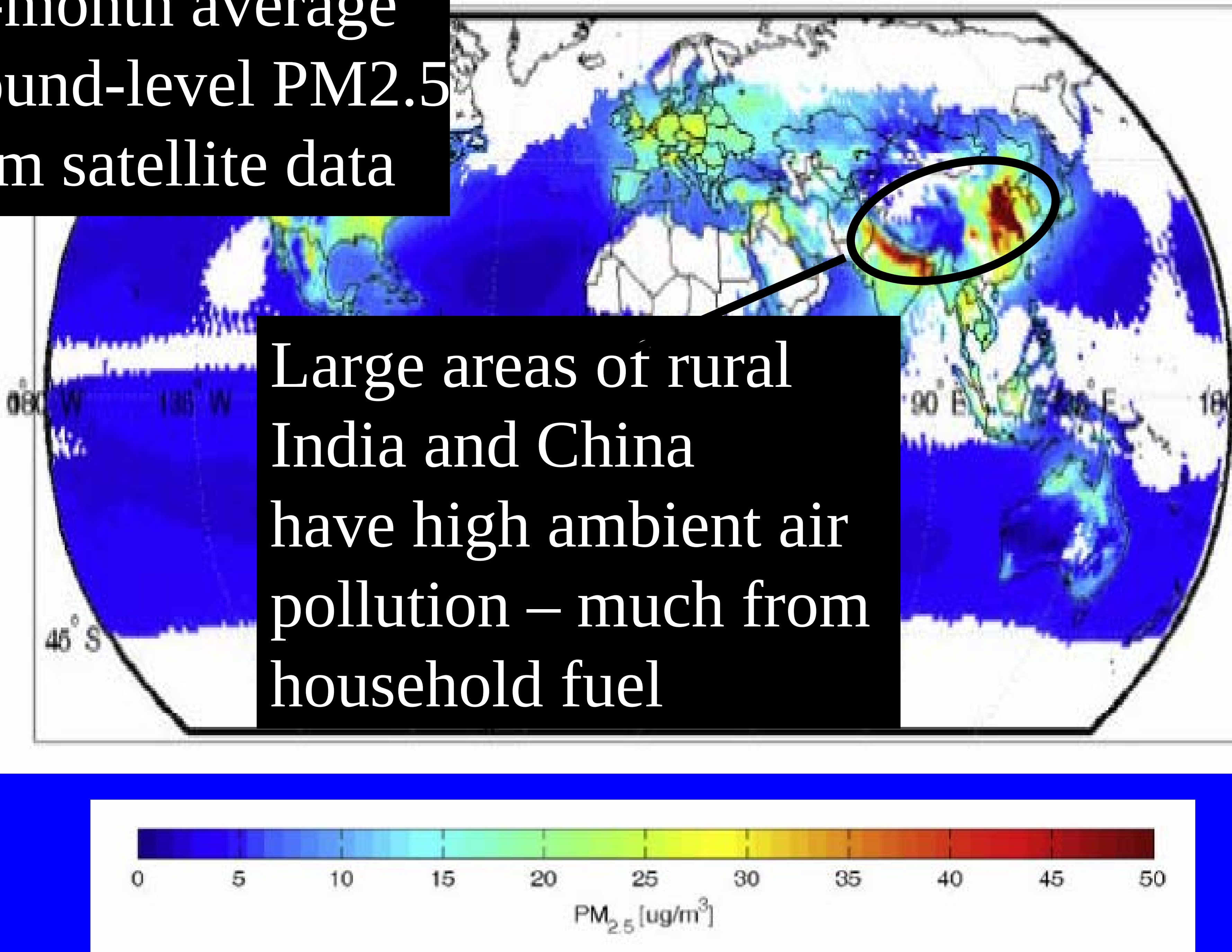

Neigborhood Pollution
Highland Guatemala
Friday, Feb 20, 2004
~6:15 AM

Neighborhood Pollution in an Indian Village



Smith, 1987

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

China National Stove Contest - 2007

	CO/CO2	Efficiency %	PM g/kg
Coal#			1.6
Tradition			4.0
Biomass			
Daxu			0.28
Jinqilin			0.20
Xintai			0.36
Zhengho			0.24

<u>Compared to traditional biomass stove</u>

28.7 g to 1.2 g small particles/meal

>20x less

Zhang, et al., 2000

*Not including water heating function

Why M&E?
You don't get what you expect, but what you inspect

Abandoned improved stove, *Guatemala*

Misplaced self-polluting chimney, *Guatemala*

Standard Methods are too slow, too imprecise, too labor intensive, and too expensive for use with millions of stoves

Fuel savings *estimation through KPT (kitchen performance test) and sales records*

Tracking ***drop out rates*** *through surveys, visits and phone interviews*

Monitoring ***reductions in indoor air pollution and black carbon emissions***

What can be done?

Where can we monitor what we do?

Small, Smart, Fast, and Cheap monitors

Available or under testing

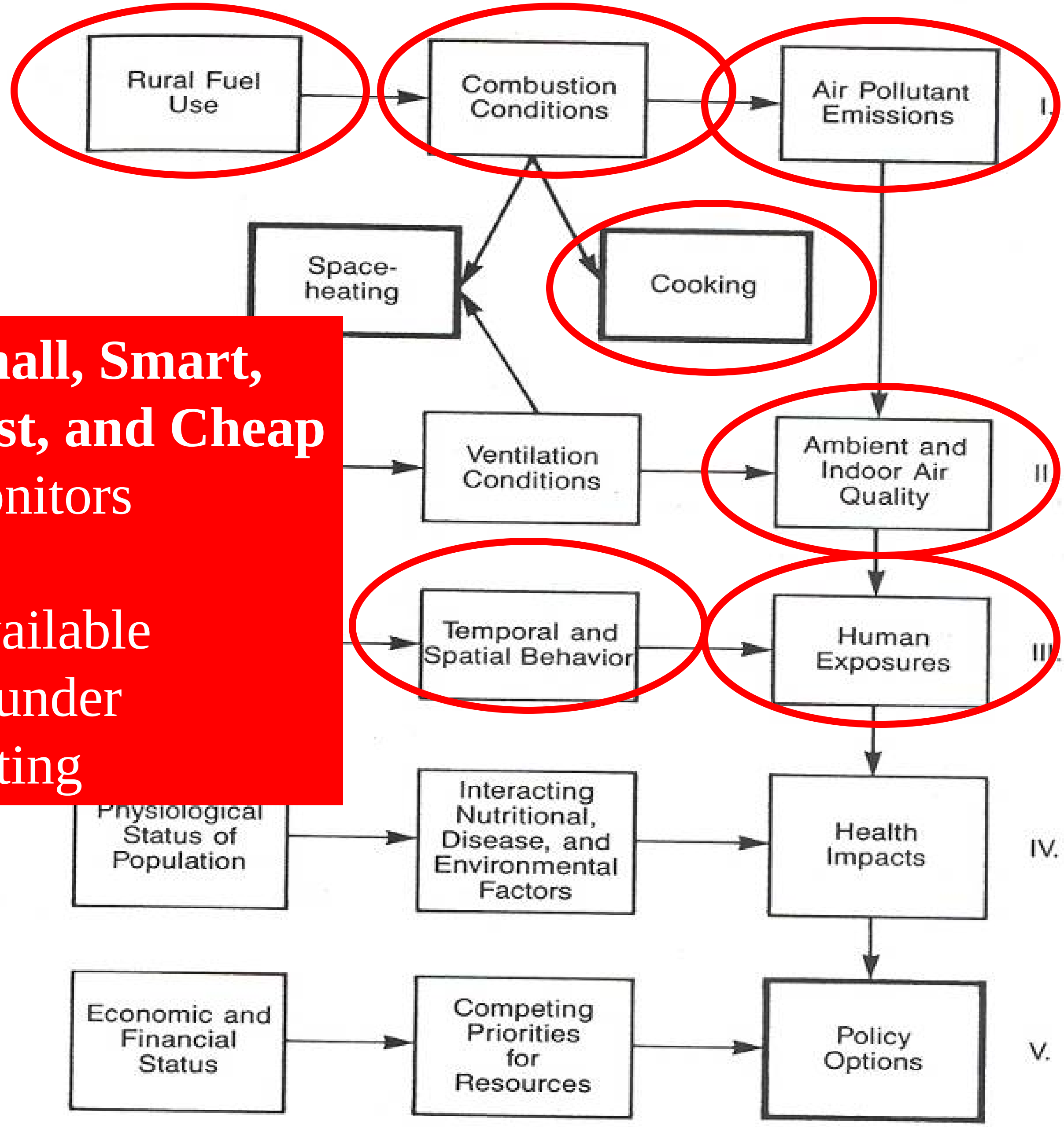


Figure 1.8. Categorization and flowchart of separate topics involved in investigating the extent and impact of air pollution exposures from combustion of biofuels in developing countries. Modified from Smith *et al.* (1983).

Smith, 1983

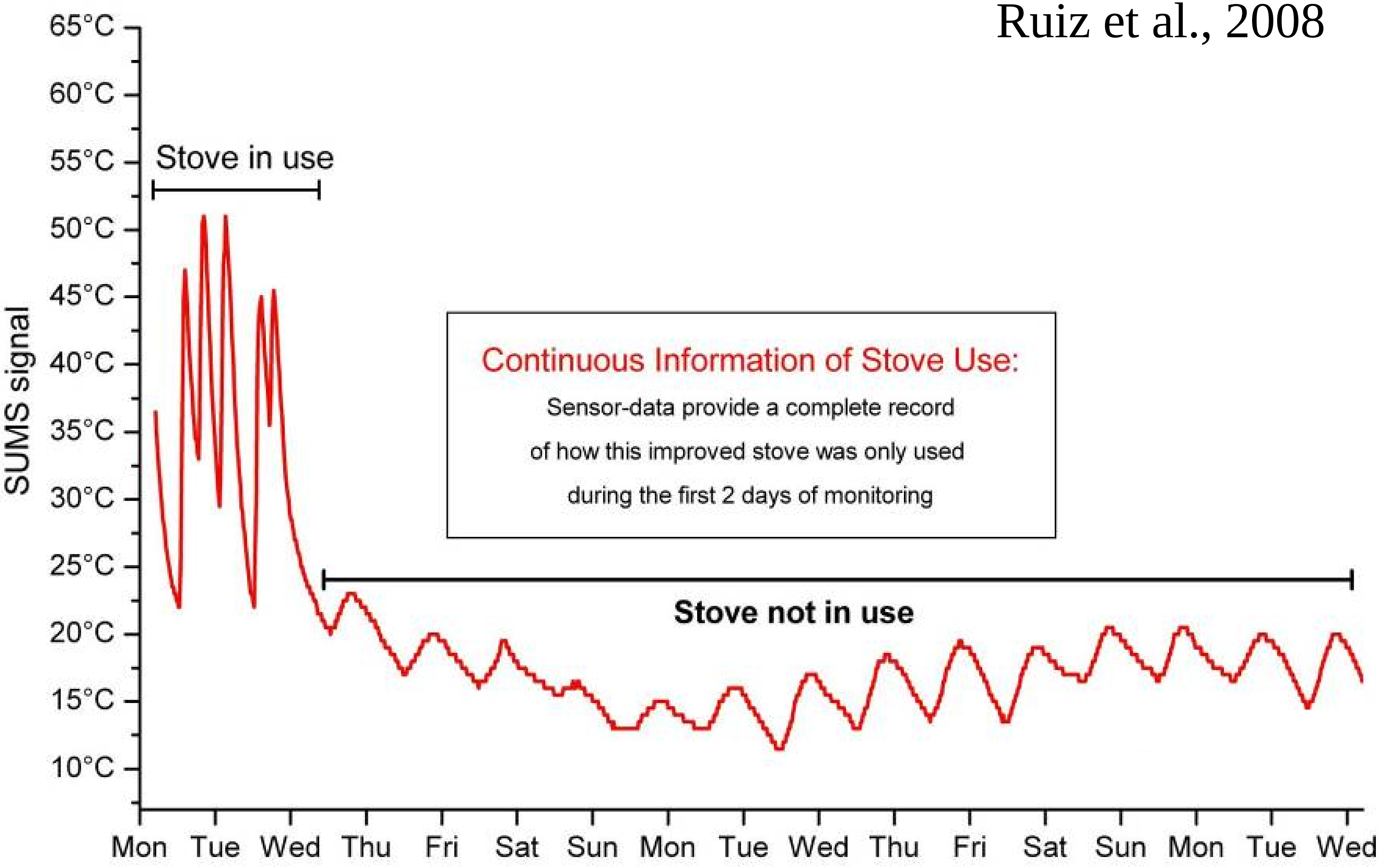
UCB-SUMS:
The Stove Use Monitoring System

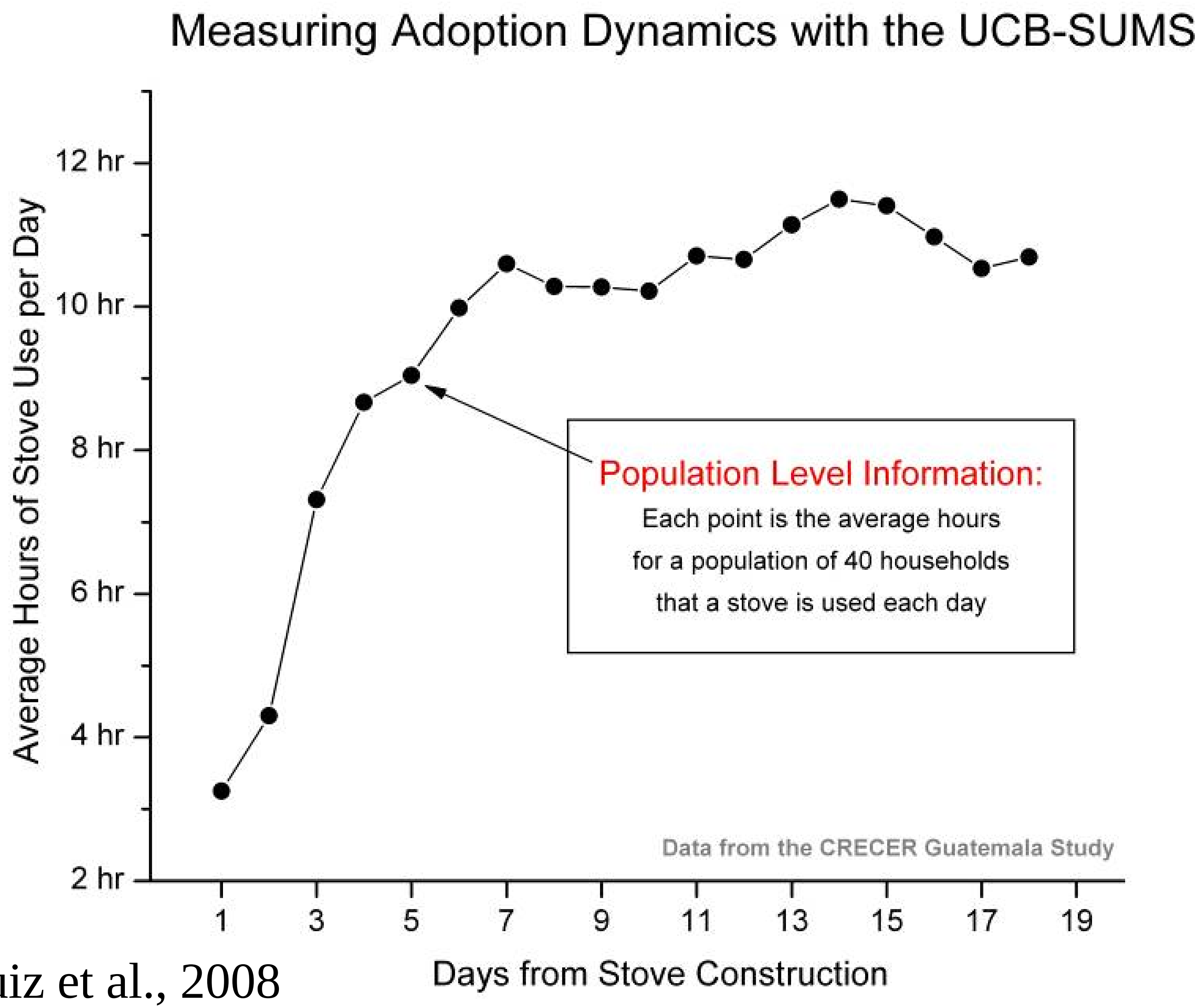
***Fuel savings** quantification using the SUMS system*

*Monitoring **drop out rates** and **patterns of use** with the SUMS system*

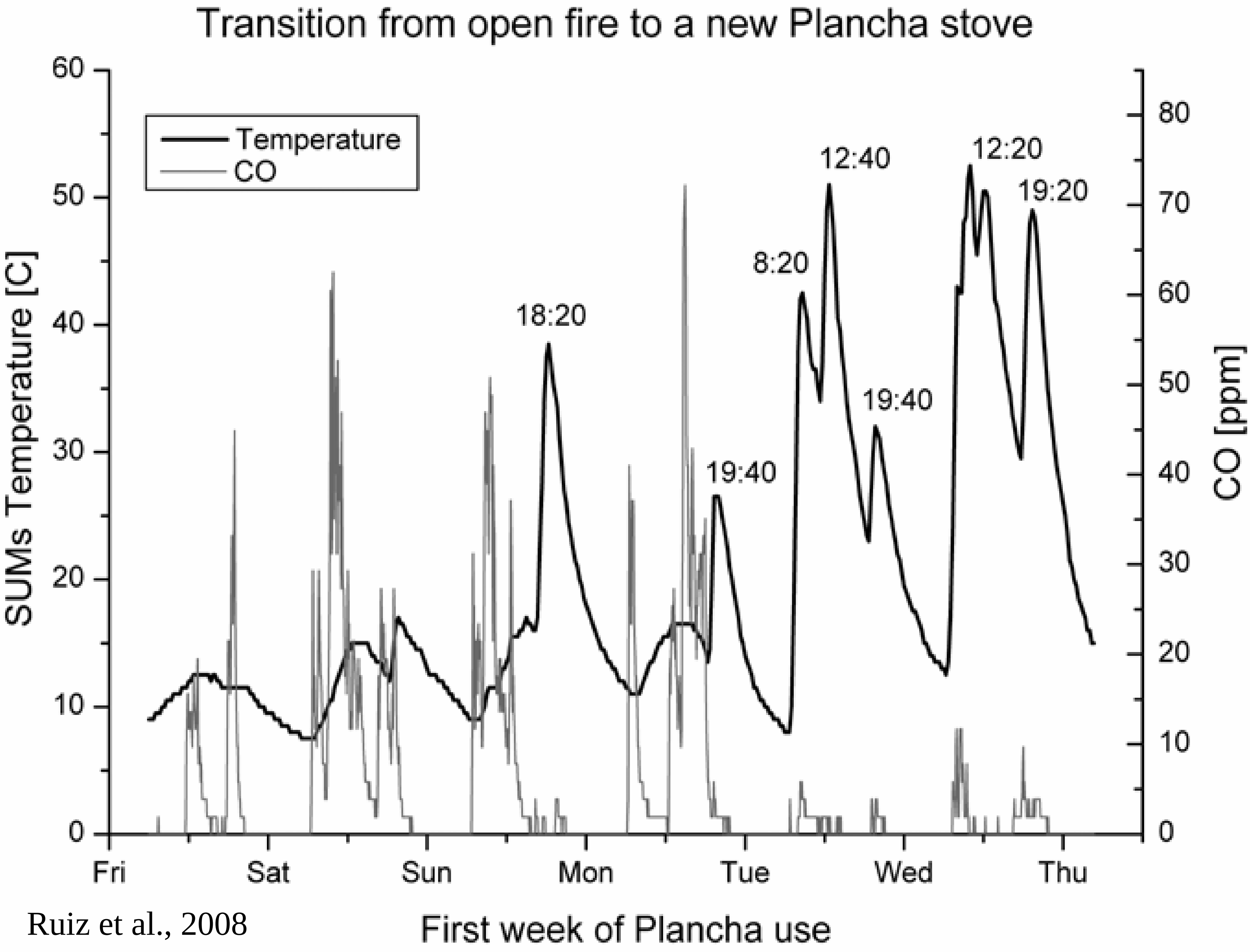
Objective Monitoring with the UCB-SUMS System

Ruiz et al., 2008

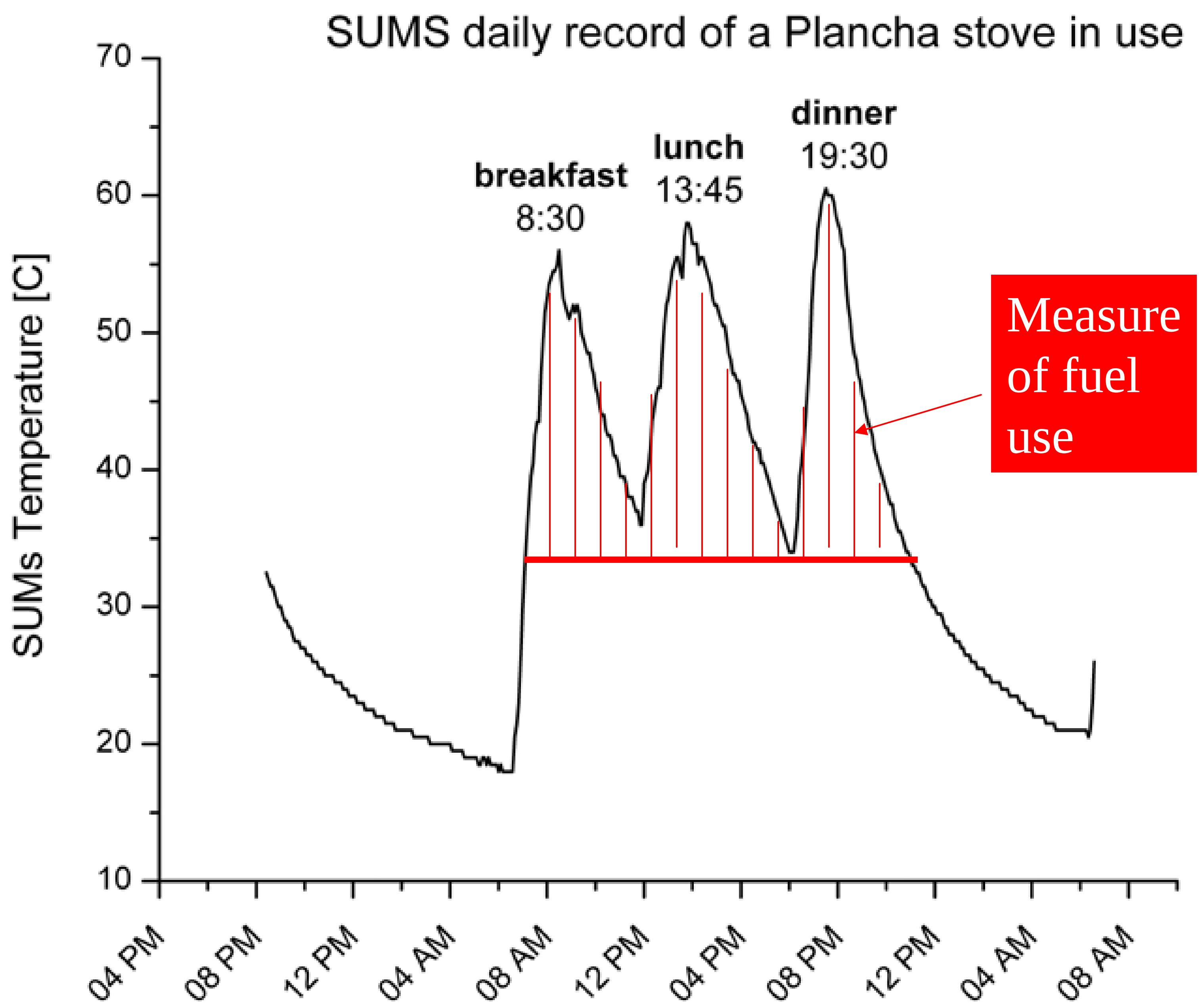


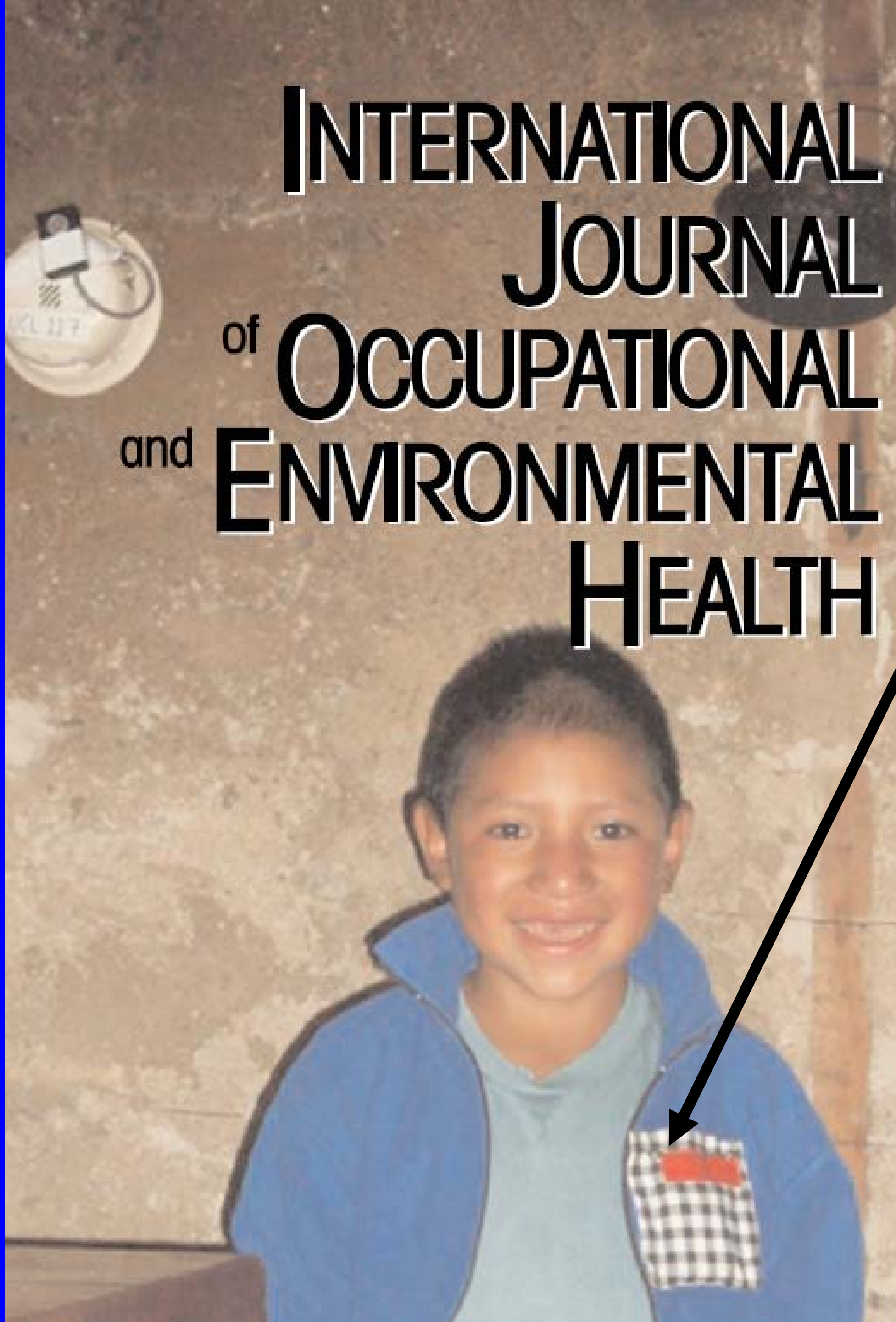


Ruiz et al., 2008



Ruiz et al., 2008


SUMS daily record of a Plancha stove in use
SUMs Temperature [C]
70
60
50
40
30
20
10
breakfast
8:30
lunch
13:45
dinner
19:30
Measure of fuel use
04 PM
08 PM
12 PM
04 AM
08 AM
12 PM
04 PM
08 PM
12 PM
04 AM
08 AM



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NOT FOR CIRCULATION

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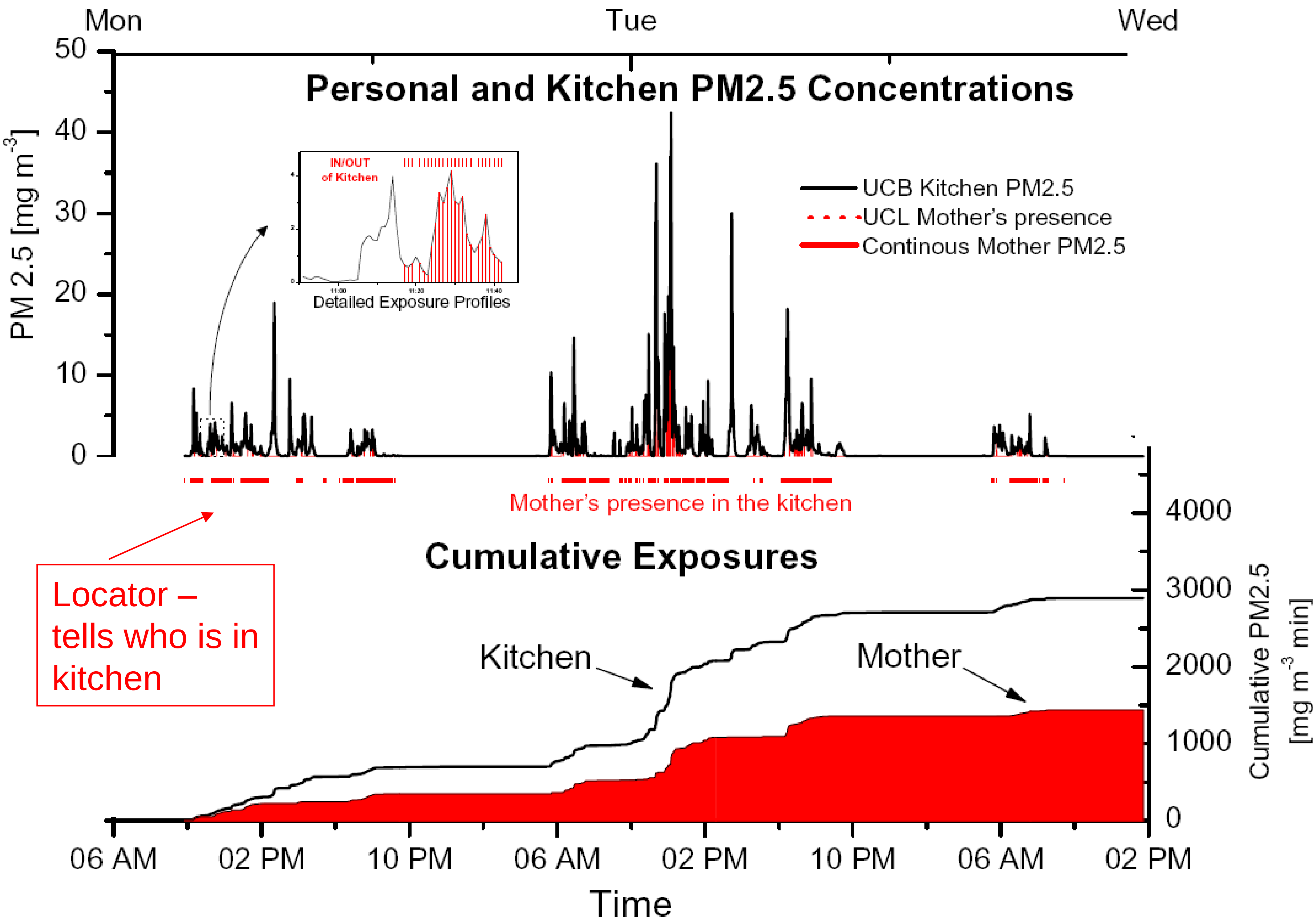
Measuring Personal Exposure to PM2.5 from Woodsmoke with the UCB-Particle Monitor and the UCB-Personal Locator



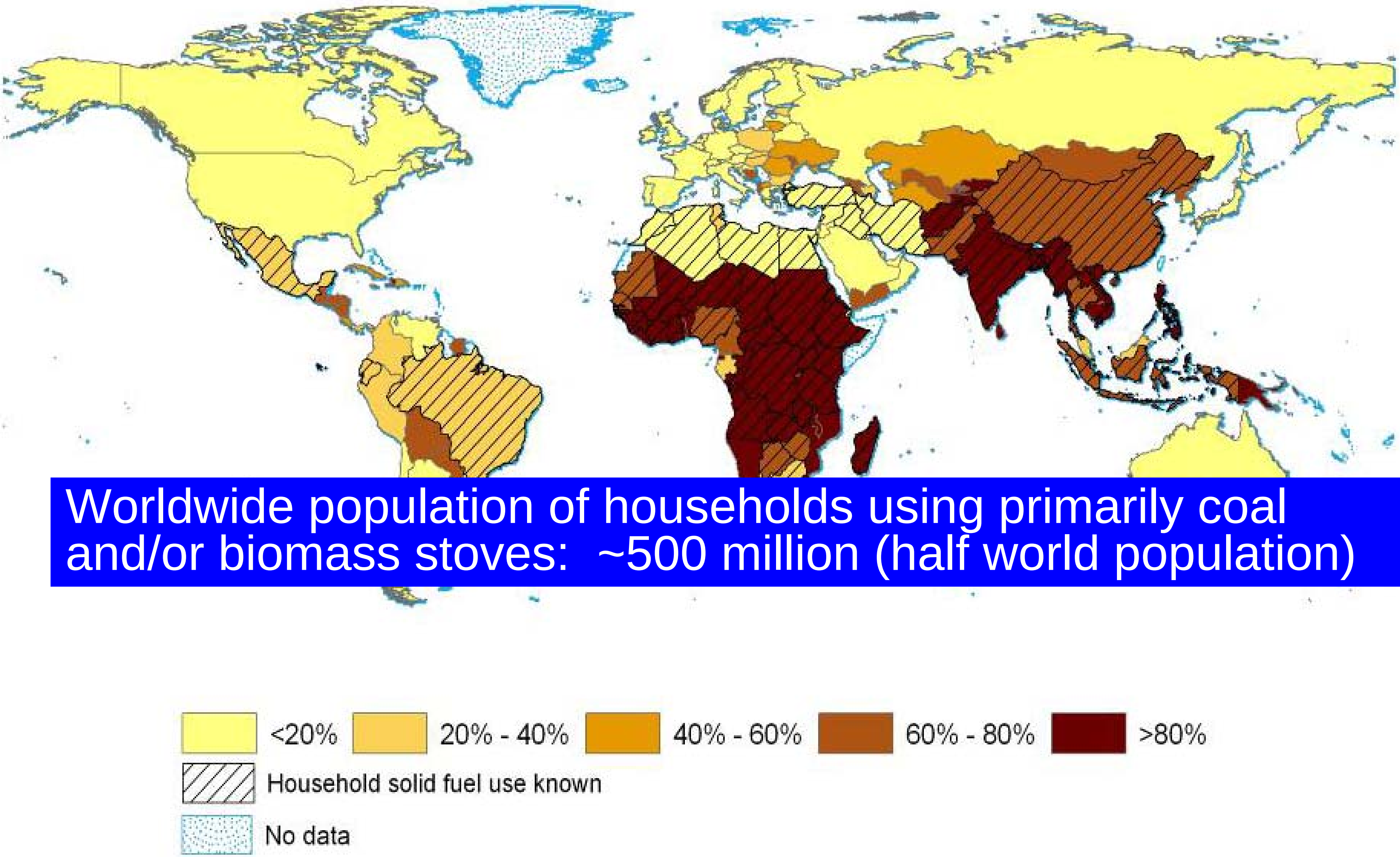
SSFC Monitors

- Available from Berkeley Air
  - UCB-PATS: particles and temperature
  - UCB-SUMS: stove use – (May, 2009)
- Active field testing
  - UCB-TAMS: time-activity
  - UCB-FUMS: fuel-use
- Under development
  - UC-BEMS: black-carbon emissions
  - UCB-PEMS: particle emissions

Bottom lines

- Health effects information is growing – more diseases and age groups
- RESPIRE provides first serious exposure-response data for one major endpoint – child pneumonia (ALRI)
  - Consistent with outdoor air pollution studies
  - Non-linear at higher levels
- Chimneys alone do not seem to reduce exposures down to levels sufficient to fully protect health
- Need to move to low-emission stoves ASAP
- M&E is vital, but new methods needed for interventions measured in 10s of millions of households

National Household Solid Fuel Use, 2000



Worldwide population of households using primarily coal and/or biomass stoves: ~500 million (half world population)

On behalf of all my colleagues and students

Thanks to funders for RESPIRE

NIEHS
WHO
Norwegian Government
Guatemala Ministry of Health
AC Griffin Trust
Kresge Foundation

And to all our participants and fieldworkers

Publications available at http://ehs.sph.berkeley.edu/krsmith/