Household Air Pollution and Health: Results from the New Comparative Risk Assessment

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

Chinese Research Academy of Environmental Science
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What is health?

- "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."
  - First of nine principles on first page of World Health Organization Constitution adopted in NYC in July 1946 by 61 nations
  - "spiritual well-being" added in 1999 by World Health Assembly, which at that time had 191 member states
    - http://www.ldb.org/iphw/whoconst.htm

How would this be operationalized for the following common queries?

- What is the total impact of disease and injury in the population? -- the overall target for public health interventions?
  - Which diseases are most important for which groups?
  - Are things getting better or worse?
- How do we compare the impacts of different risk factors and potential interventions that affect different populations?
  - For example, what is the burden of disease from environmental factors?
  - How does the impact of tobacco smoking compare to that from air pollution?

Health Effects

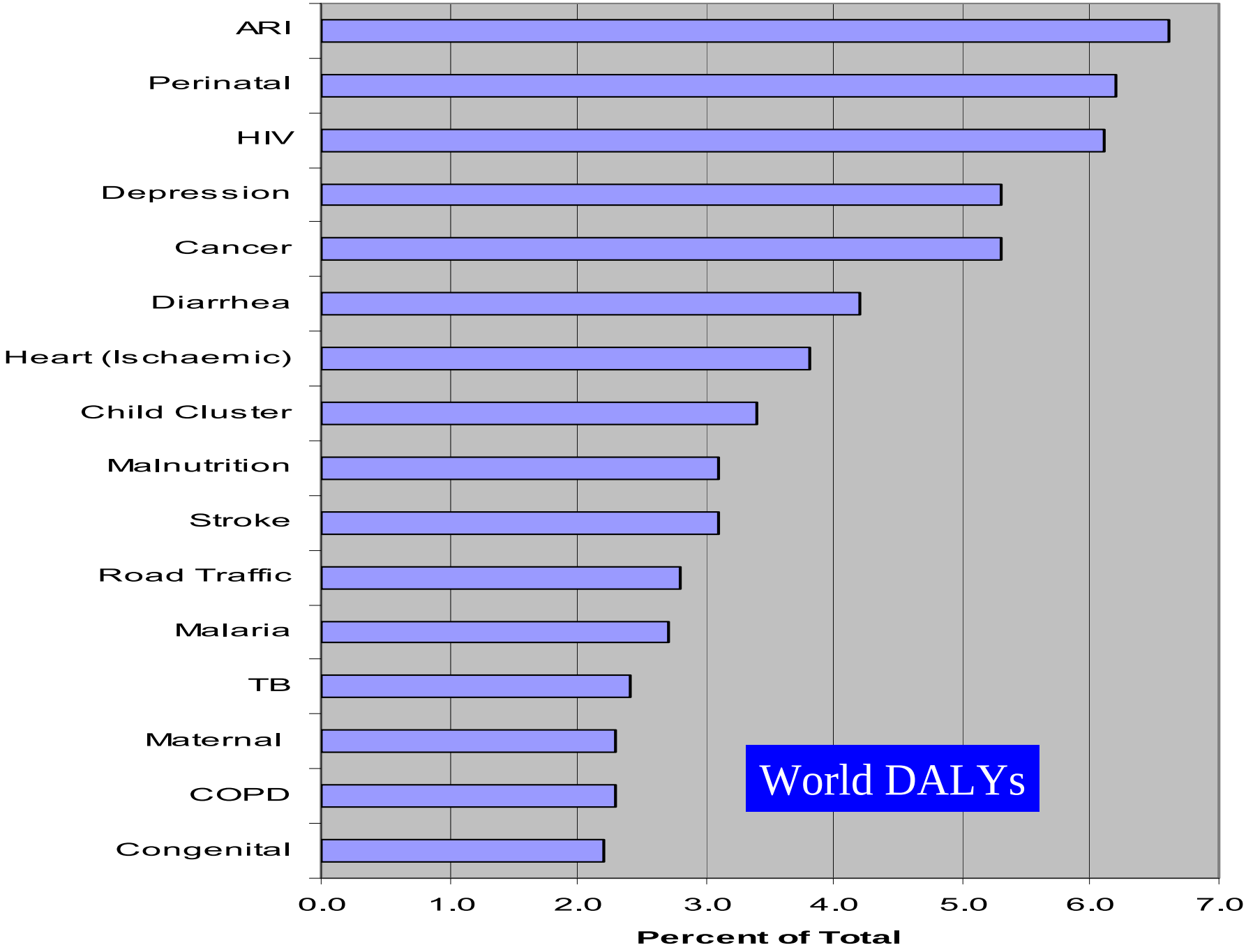
- Example of results from outdoor air pollution studies
  - Asthma attacks
  - Missing workdays
  - Missing school days
  - Days with cough
  - Emergency room visits
  - Hospital admissions
  - Physician visits
  - Medication use
  - Daily death rate
  - Lung function
  - Self-reported health status
  - Etc.
- How can these be compared across time, cities, countries, age groups, sectors (e.g., transport versus power plants), etc.?
- Let alone compared with the health impacts from completely different risk factors, such as water pollution, lead exposure, high cholesterol, unsafe sex, etc.?

Combined Measure of Ill-Health

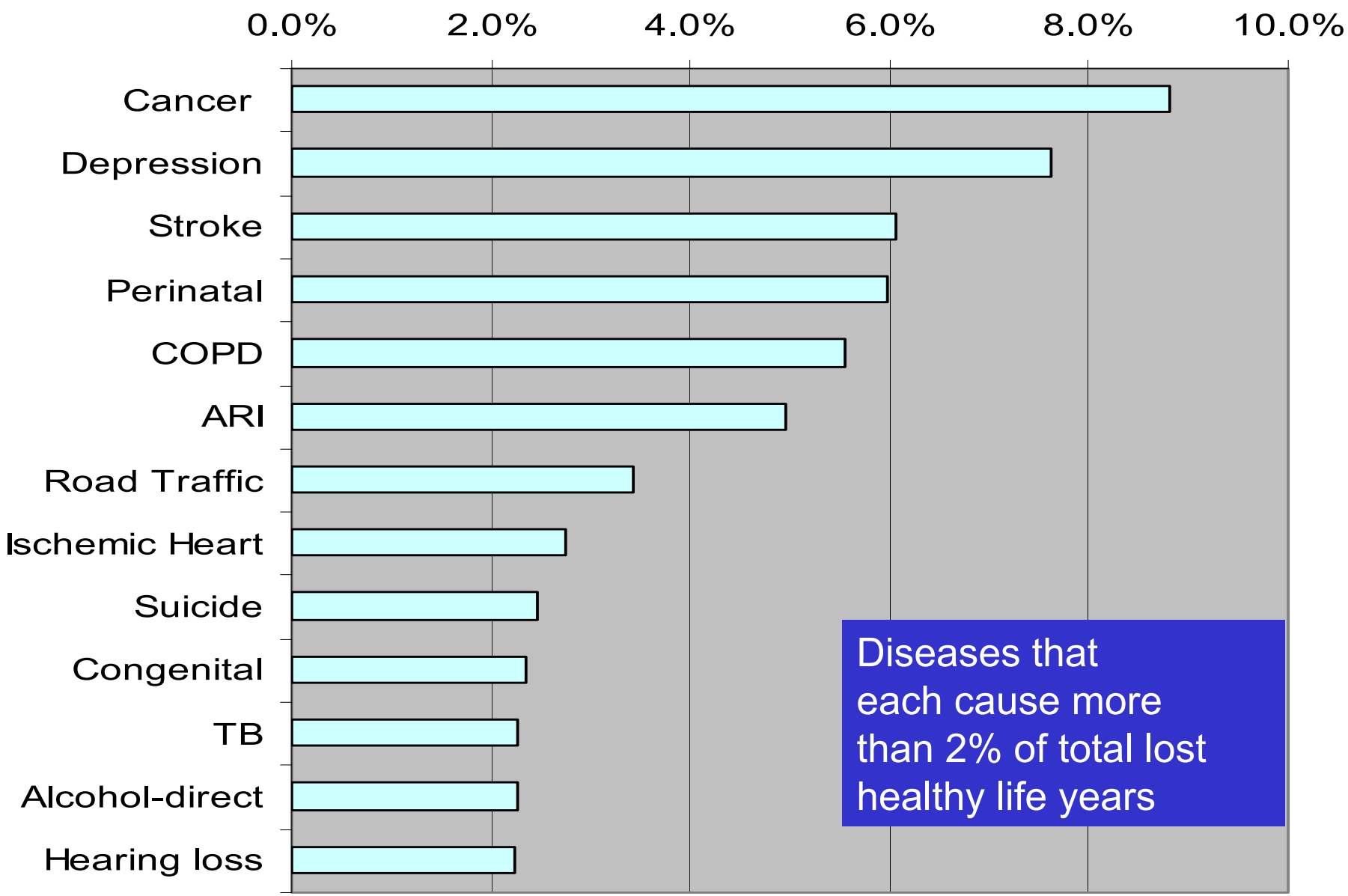
- Most fundamental deprivation is loss of **time**:
  - Same potential life length shared by all humans
  - The degree to which a person does not achieve this life length is a measure of ill-health
  - Can be used for disabilities, as well, but need to weight relative severity of disabilities as well as tabulate their duration

Disability Adjusted Life Year
The DALY

- Principle #1: The only differences in the rating of a death or disability should be due to age and sex, not to income, culture, location, social class.
- Principle #2: Everyone in the world has right to best life expectancy in world
- DALY = YLL + YLD
  - Years of Lost Life (due to premature mortality)
  - Years Lost to Disability (due to injury & illness)


ARI
Perinatal
HIV
Depression
Cancer
Diarrhea
Heart (Ischaemic)
Child Cluster
Malnutrition
Stroke
Road Traffic
Malaria
TB
Maternal
COPD
Congenital
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Percent of Total
World DALYs

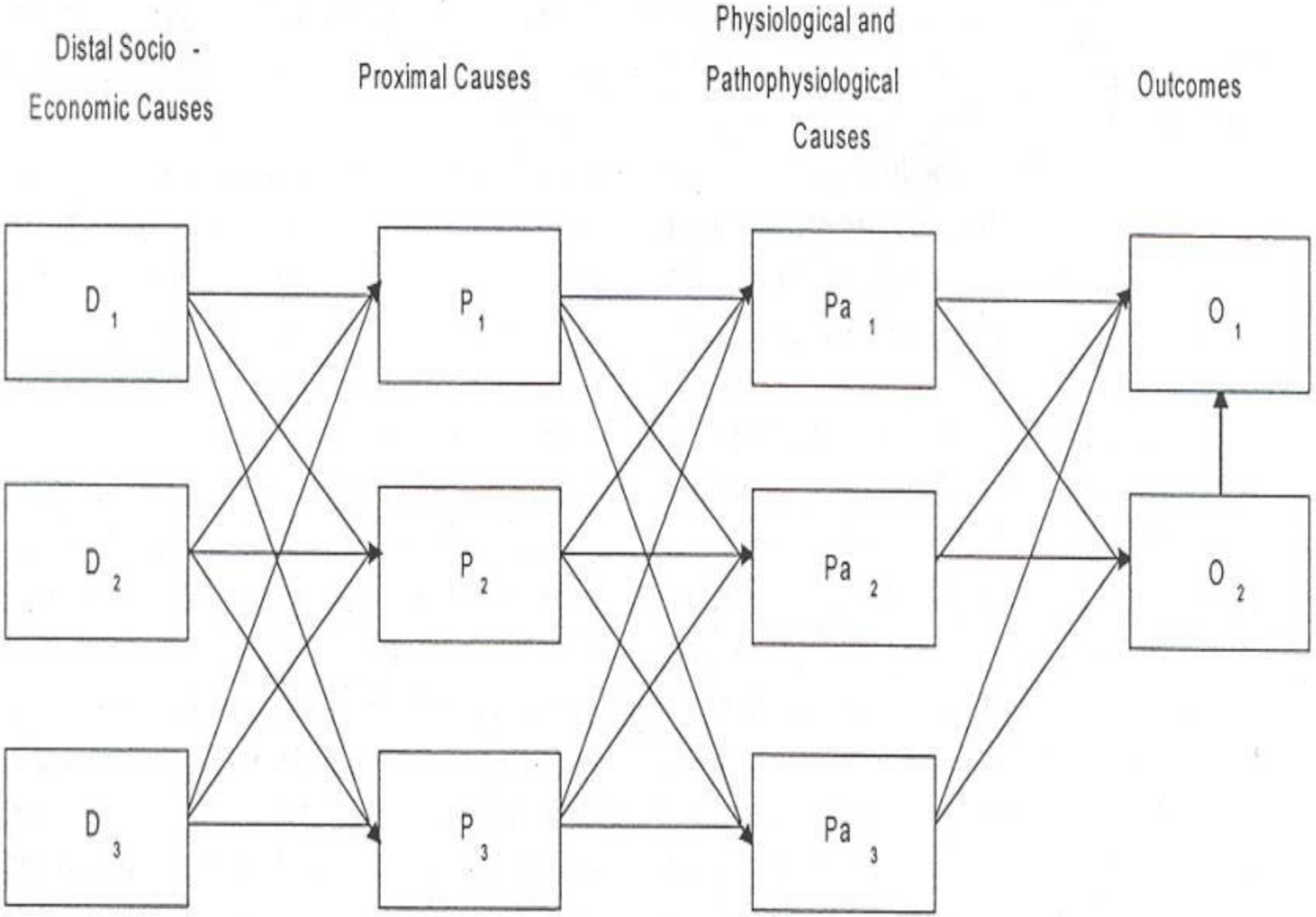
Chinese Burden of Disease

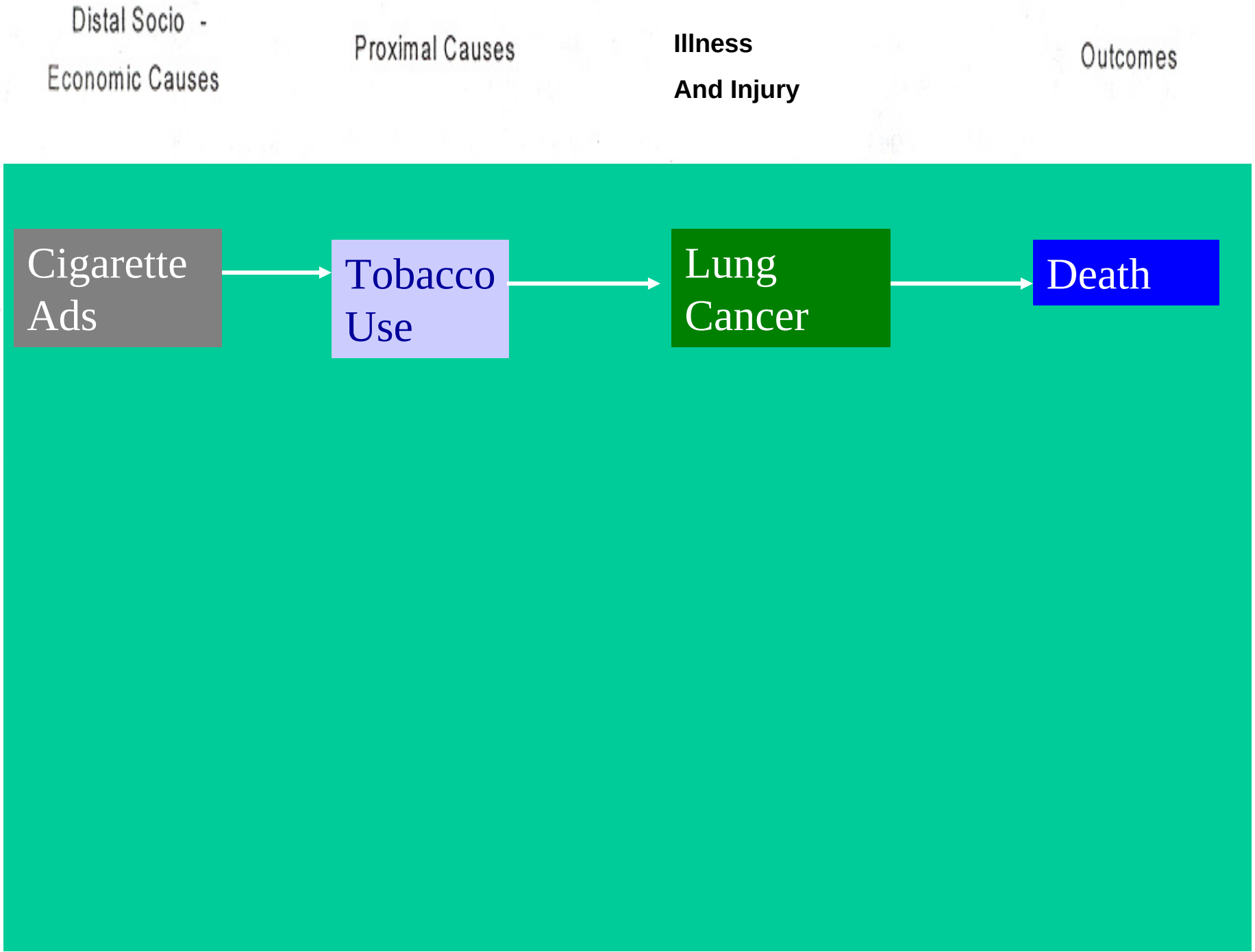


We have a means to answer the first, but what about the second?

- What is the total impact of disease and injury in the population? -- the overall target for public health interventions?
  - Which diseases are most important for which groups?
  - Are things getting better or worse?
- How do we compare the impacts of different risk factors and potential interventions that affect different populations?
  - For example, what is the burden of disease from environmental factors?
  - How does the impact of tobacco smoking compare to that from air pollution?

Introduction to Comparative Risk Assessment



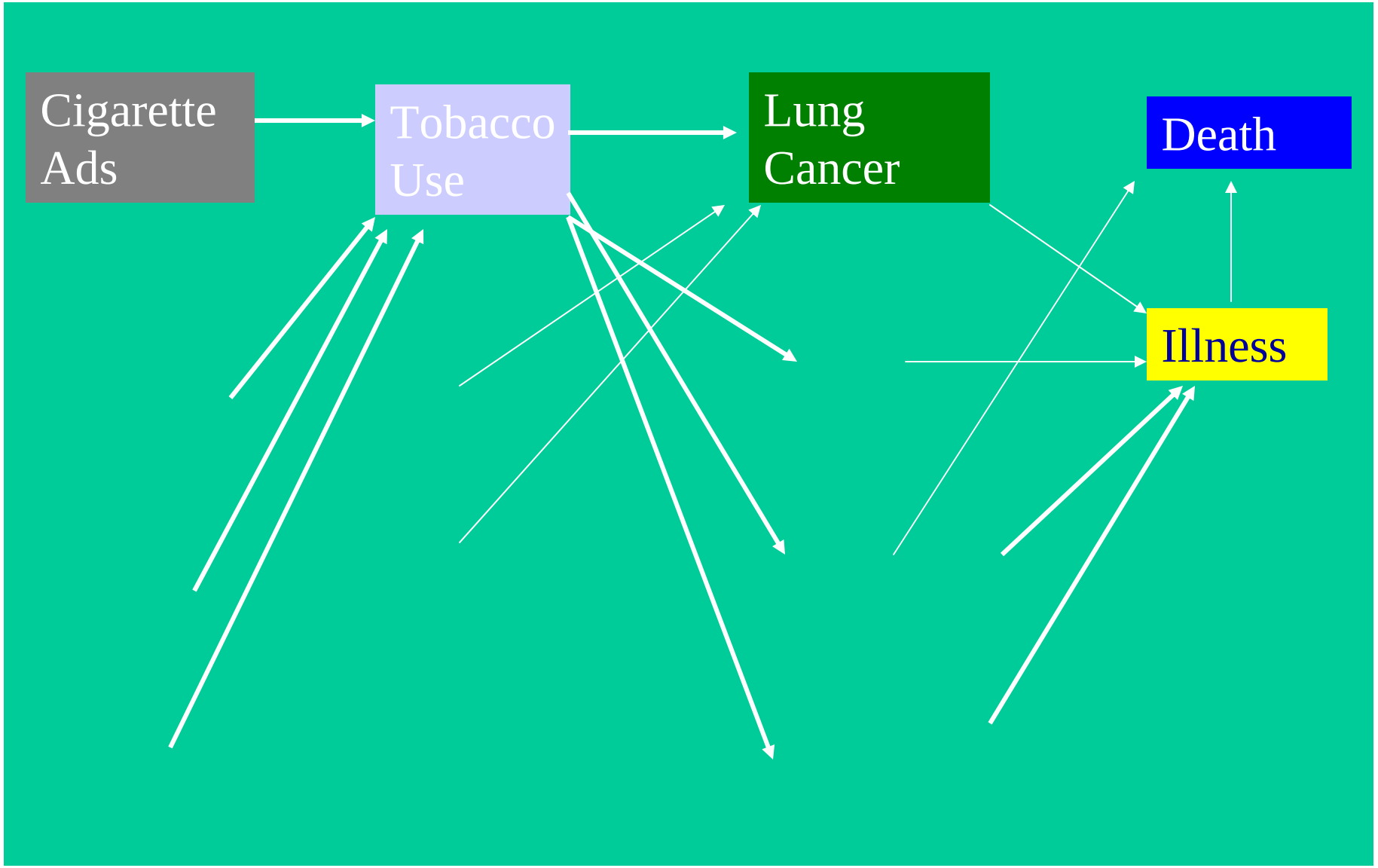

Distal Socio -
Economic Causes
Proximal Causes
Illness
And Injury
Outcomes
Cigarette Ads
Tobacco Use
Lung Cancer
Death

Distal Socio - Economic Causes

Proximal Causes

Illness And Injury

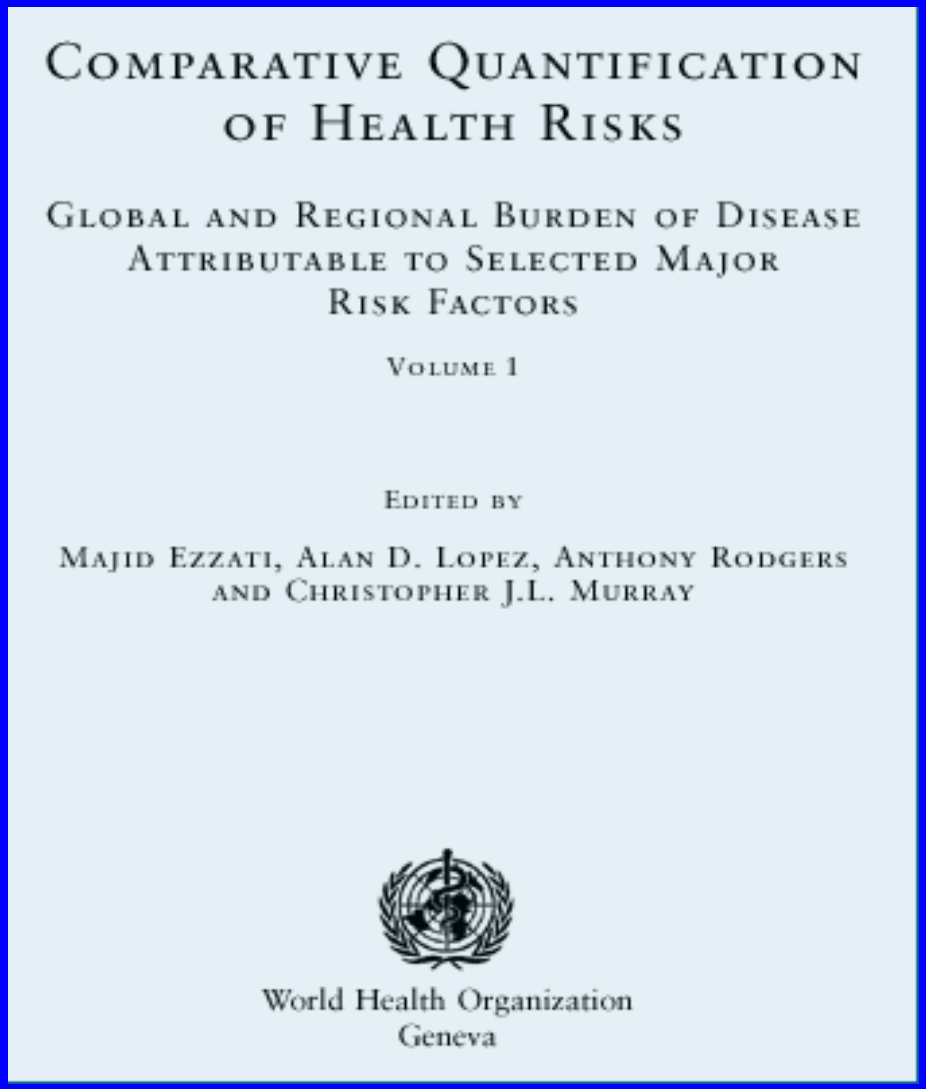
Outcomes



Comparative Risk Assessment Project
2-year 30-institution study organized by WHO

Disease, injury, and death due to major risk factors calculated by age, sex, and 14 global regions.

Published in summary form in the
Published in 2 vols (2500 pp), Fall 2004
(being revised and updated 2010)



(available on WHO CRA website)

WHO-led Program to Develop Global Burden of Disease Estimates for 26 Major Risk Factors

- More policy relevant and, usually, more distal risk factors than disease or cause of death.
- Represent viable interventions for which cost-effectiveness can be determined.
- Common methods and criteria for including evidence used across risk factors.

Risk Factors in WHO 2002 Comparative Risk Assessment

- Malnutrition (underweight)
- Micronutrient deficiency (Zn, Fe, Vit-A)
- Hypertension
- Cholesterol
- Obesity/BMI
- Lack of fruit & veg
- Physical inactivity
- Lack of contraception
- Unsafe sex
- Unsafe medical injection
- Childhood sexual abuse
- Tobacco (active smoking)
- Illicit drugs
- Alcohol
- Lead (Pb)
- Water/hygiene/sanitation
- Climate change
- Indoor air pollution
- Urban outdoor air pollution
- Occupational hazards (several types)

Attributable Risk?

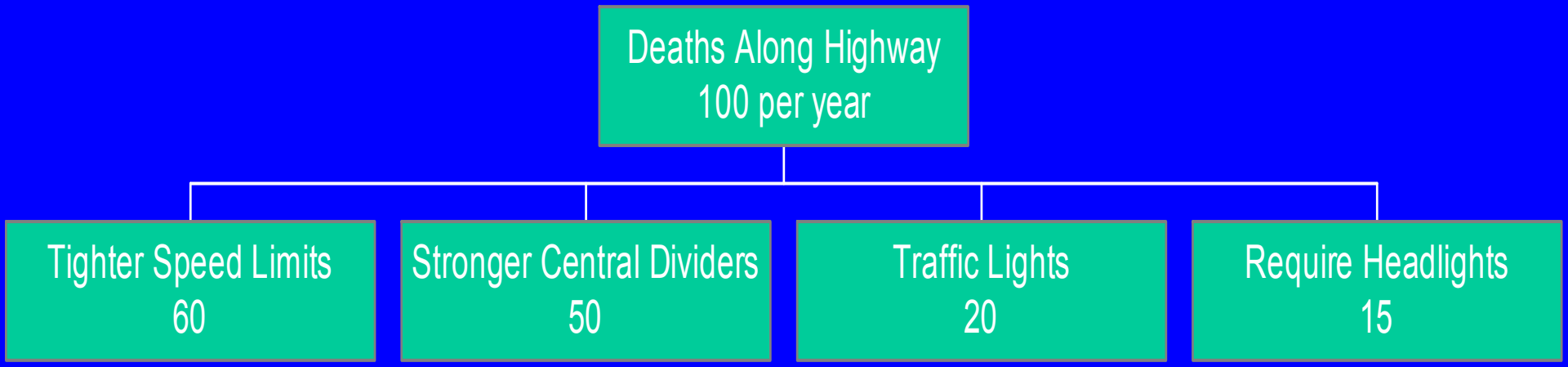
- The amount of ill-health that would not exist today if the exposure to the risk factor had not occurred in the past.
- Assumes all other risk factors remain constant
- Counter-factual level important, i.e., what lower exposure level would have been possible?

Characteristics of Attributable Risk

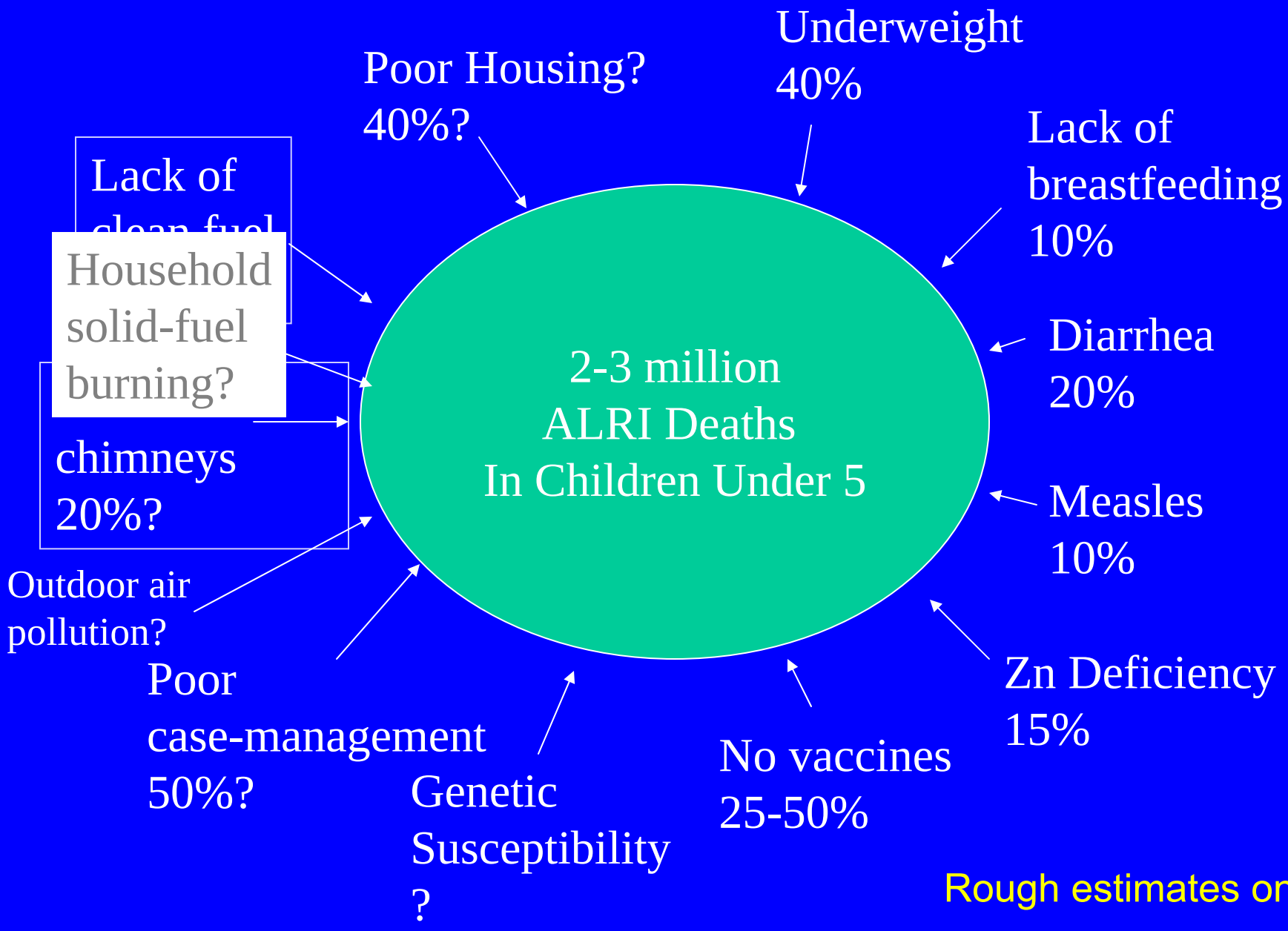
- All attributable risks for a disease often add up to much more than 100%
- Size of attributable risk for a particular risk factor depends on the order that different factors are examined
- Presumes the existence of a feasible intervention to lower exposure.

How attributable risks can add to more than 100%

Attributable deaths to various causes along a section of highway

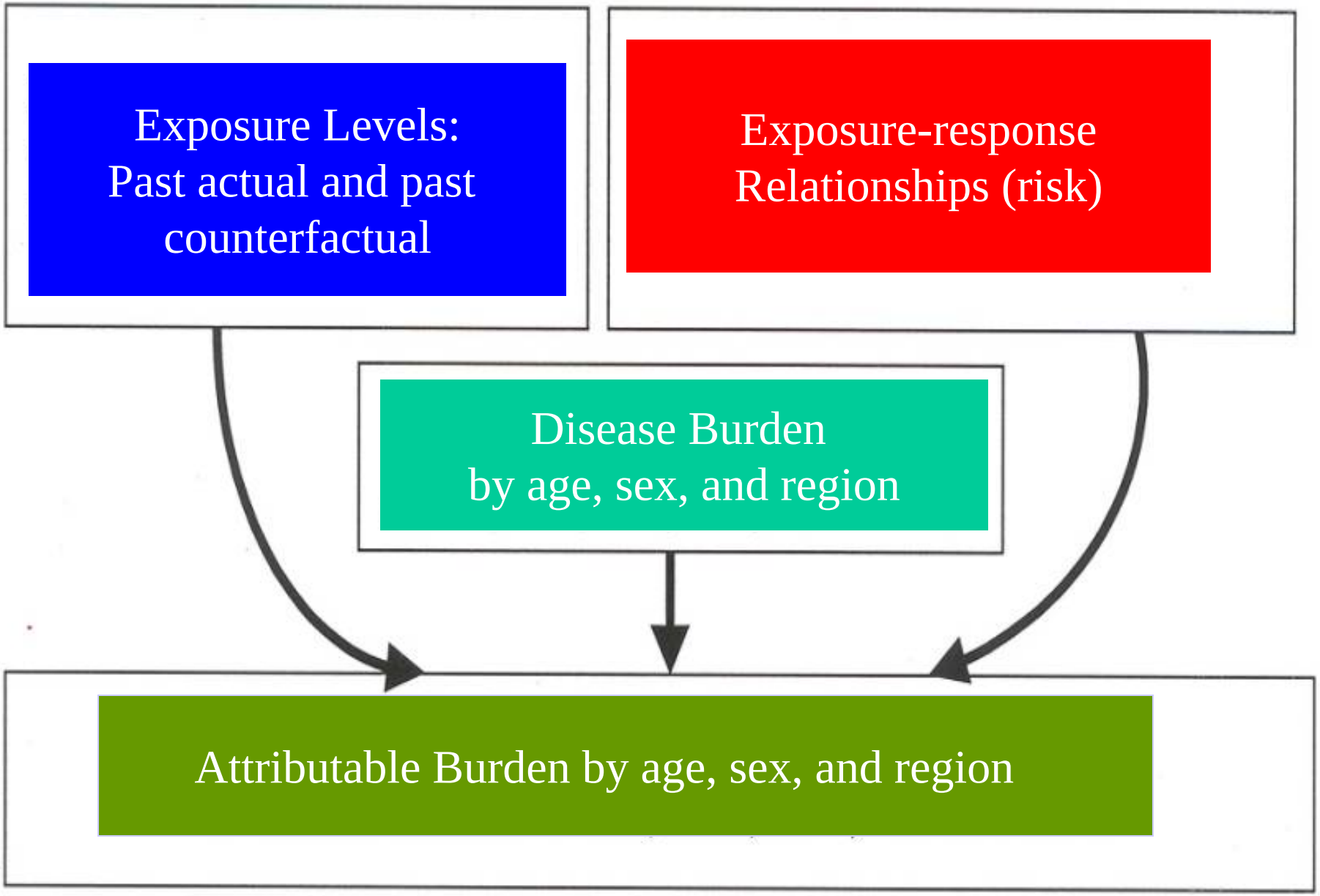


Attributable Fractions do not add to 100%



Rough estimates only

Comparative Risk Assessment Method



CRA Method

- Estimate prevalence of exposure = Pe
- Relative risk estimates from epidemiological studies = RR
- Population Attributable Risk (PAR)

  PAR= Pe(RR-1) / (1+ Pe(RR-1))

- Morbidity and mortality estimates from the Global Burden of Disease database *(WHO updated annually)*

  Attributable Burden = PAR * Background disease

Attributable deaths from outdoor air pollution

1. RR is the relative risk of death from a particular disease due to the measured exposure:

   $RR = [(RR_0 - 1) * (Em - Ecf)] + 1$

   RR_0 is the increase in deaths per unit exposure derived from epidemiological studies
   Em is the measured concentration of pollution
   Ecf is the counterfactual level below which we cannot go

2. Attributable Fraction (AF) due to outdoor air pollution

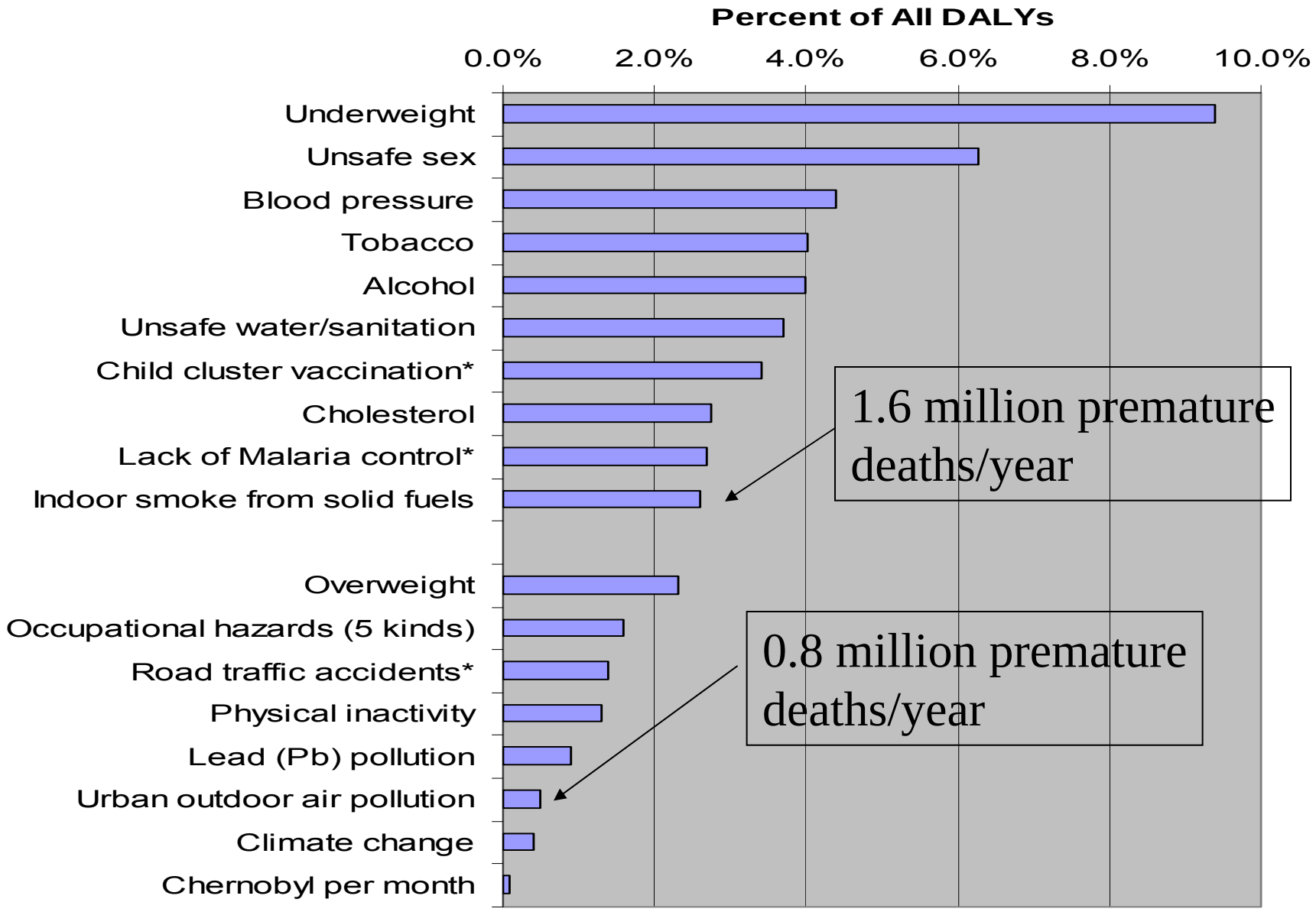
   $AF = F(RR-1) / [F(RR-1)+1]$

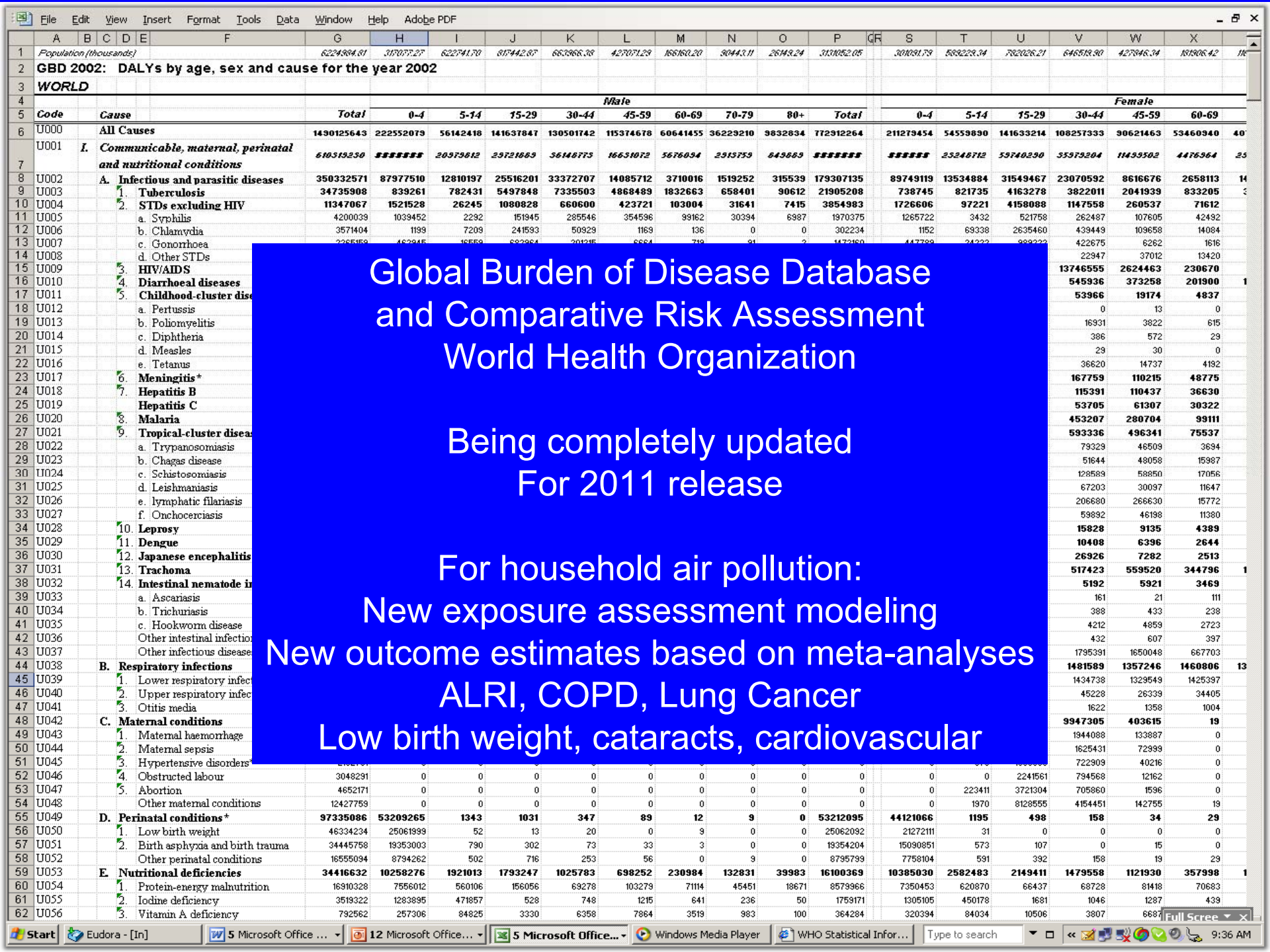
   where F is the proportion of people exposed to outdoor air pollution (here assumed to be 100%)

3. Attributable deaths = AF * total deaths for this disease in the population

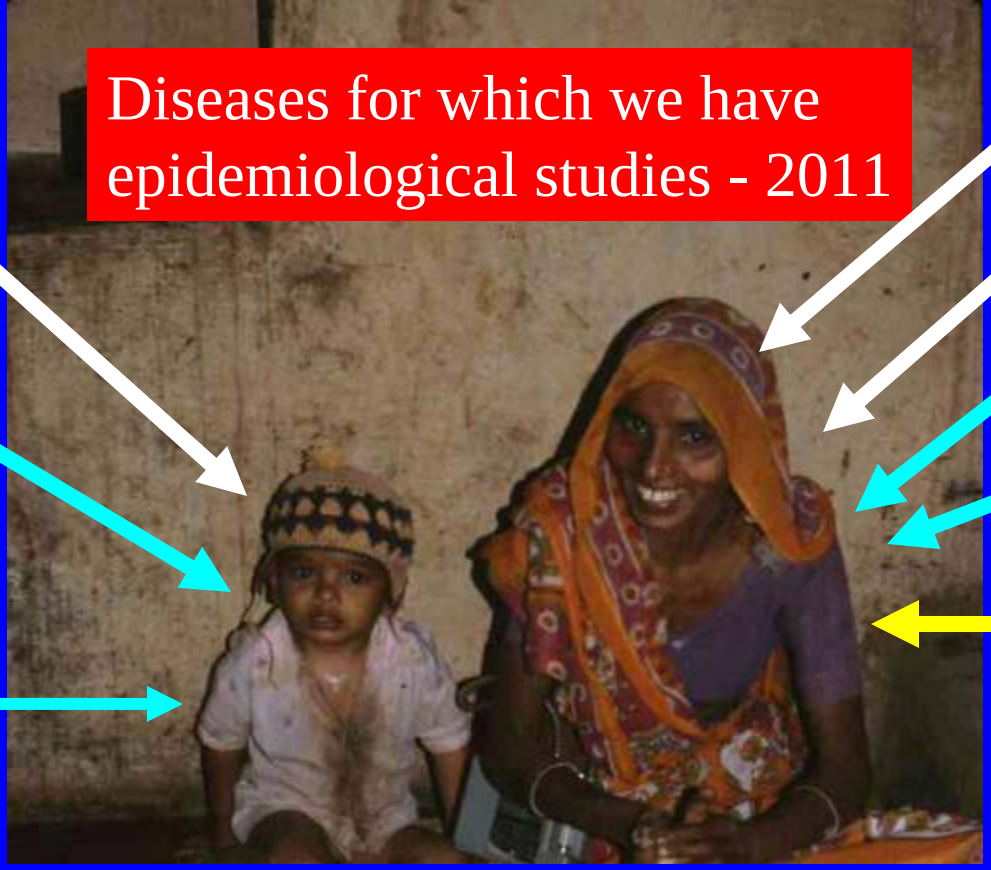
Global Burden of Disease from Top 10 Risk Factors

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?

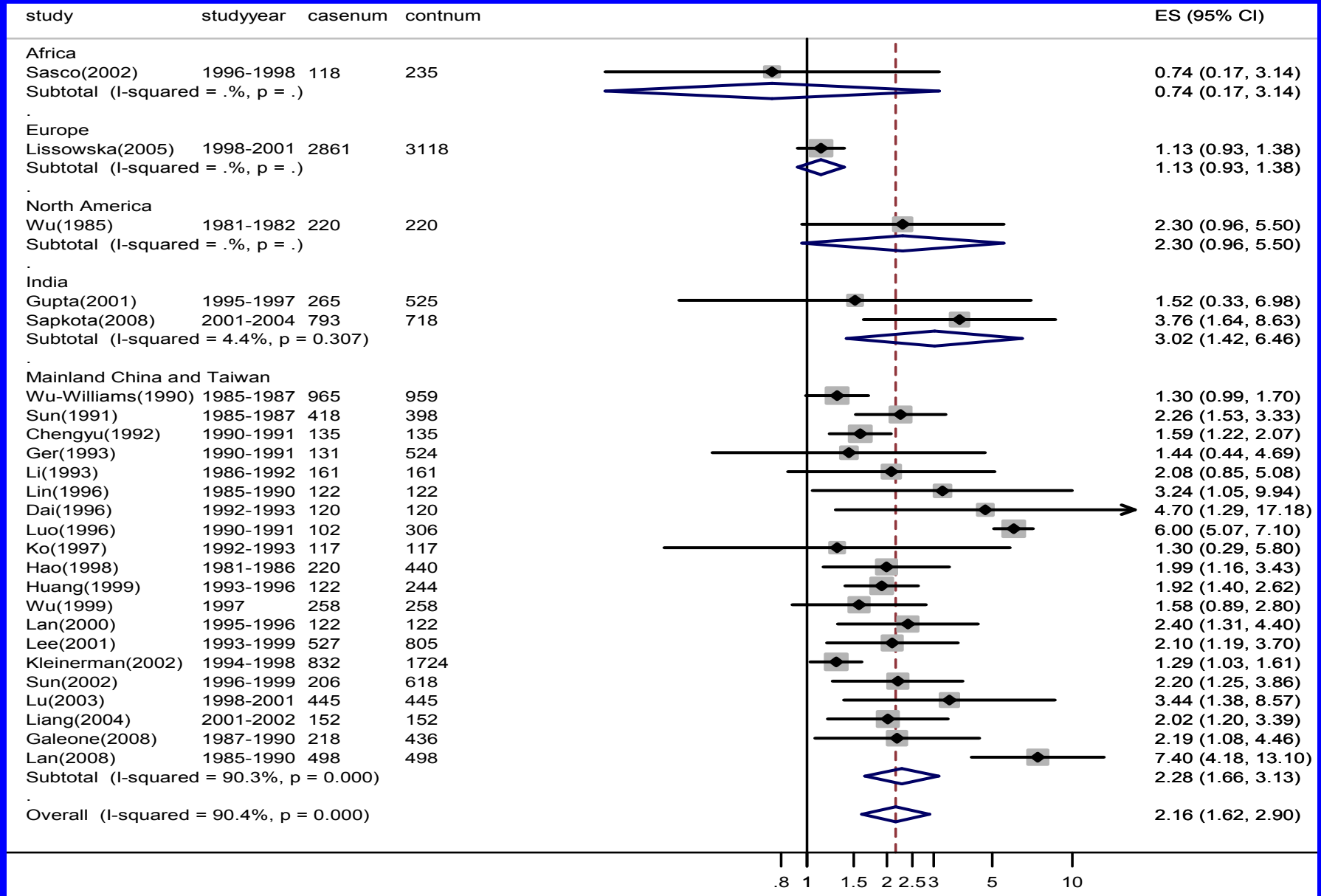
Tuberculosis

ALRI

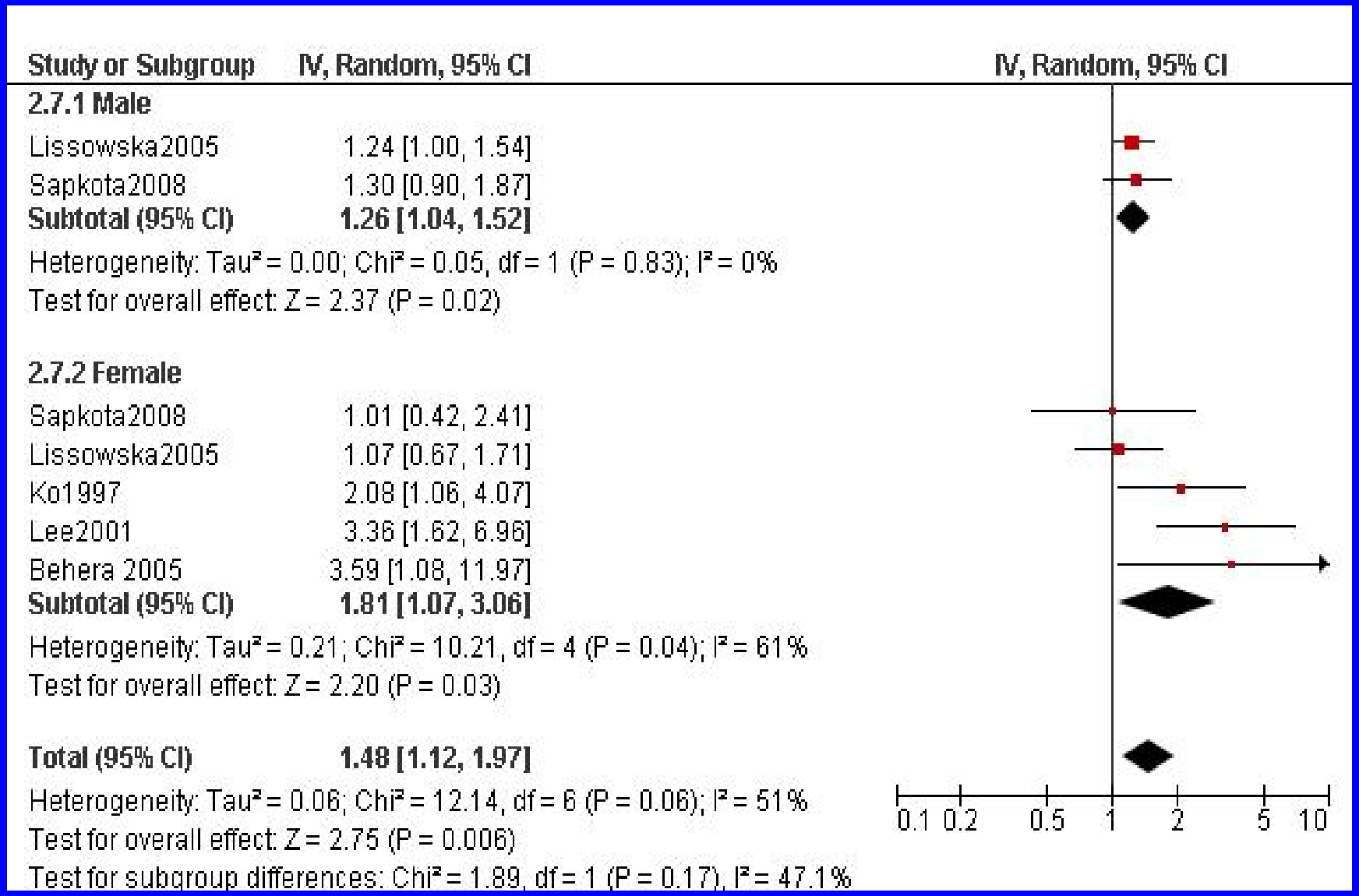
Other cancers (cervical, NP, upper airway)

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

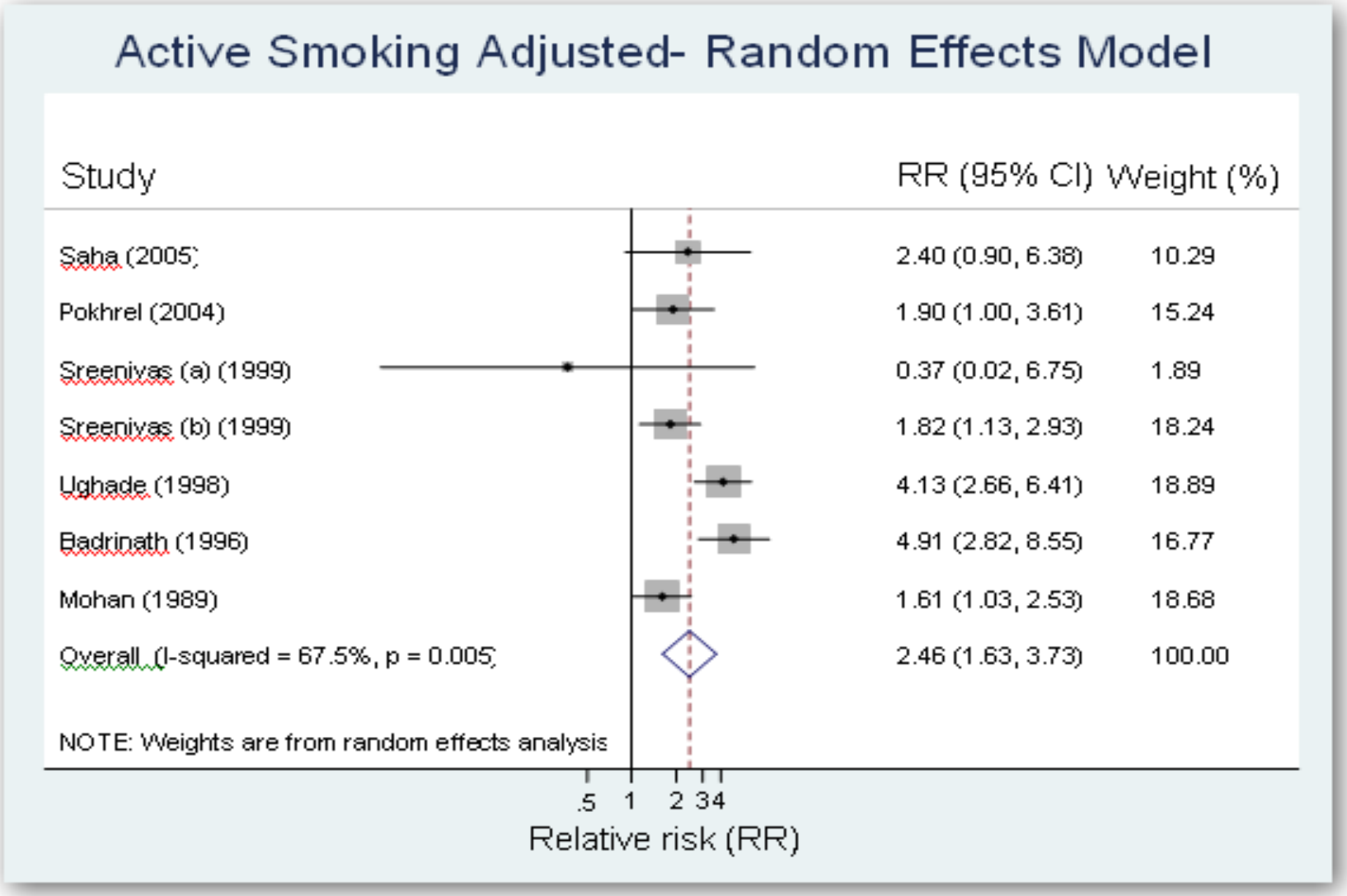


Lung Cancer: Biomass vs. clean fuel



CRA, Imran et al. preliminary

Cataracts and Biomass Cooking Smoke*



* Adjusted for UV

CRA Preliminary, Adair et al.

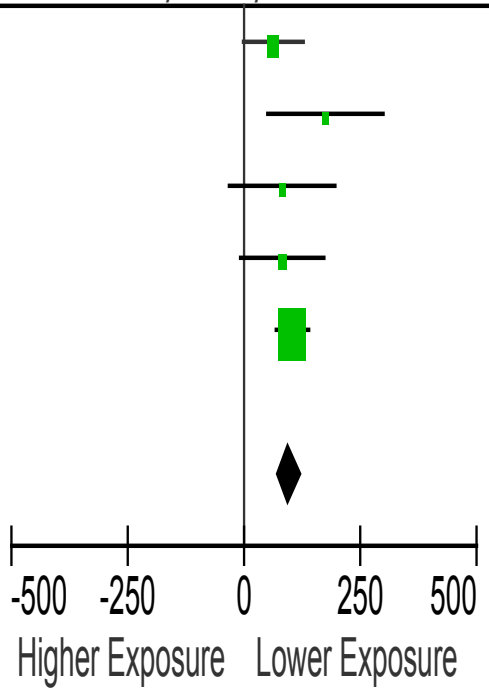
Pooled birth weight difference (low minus high exposure):

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: $Z = 6.74$ ($P < 0.00001$)



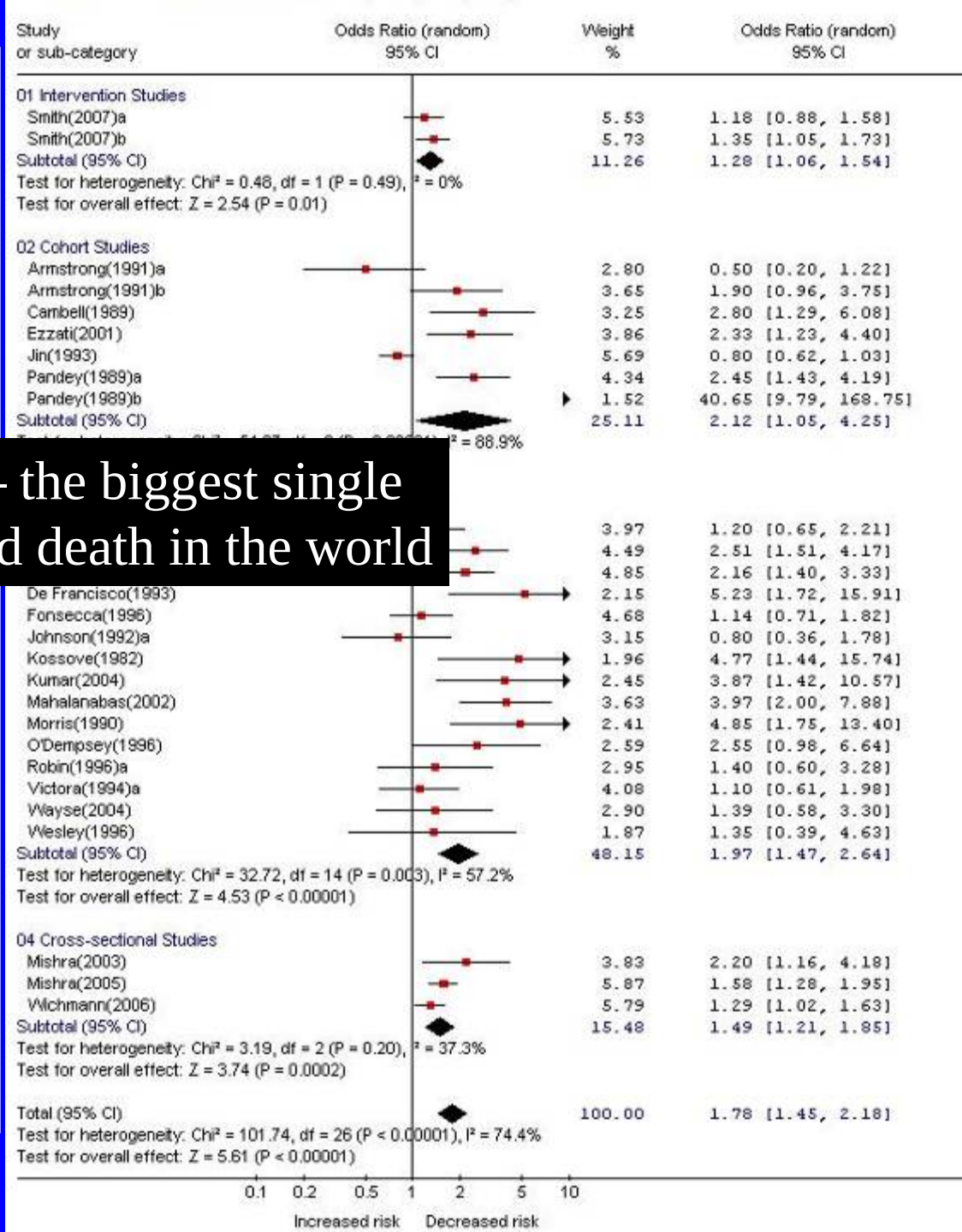
All estimates: +96.6g (68.5, 124.7)

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)



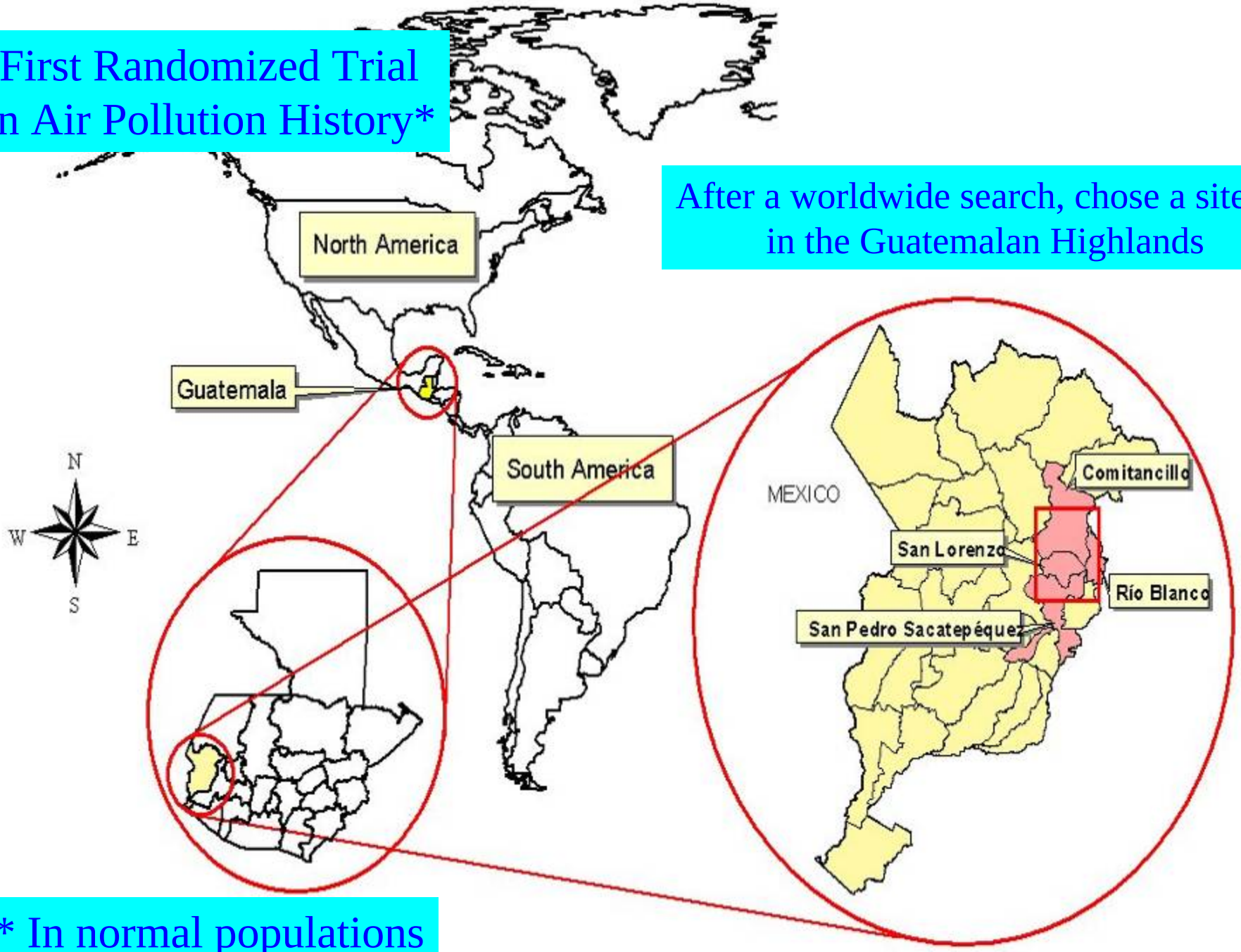
Pneumonia – the biggest single cause of child death in the world

Preliminary CRA Effect Estimates

Health Outcome	Sex	Age	Level of Outcome	Risk Estimate
ALRI	M & F	< 60 mo	Ia	1.78 (1.45 to 2.18)
ALRI: exposure/response	M&F	< 60 mo	Ib	2.3 (95% CI ?)
COPD	F	>15 yr	Ia	2.7 (1.95 to 3.75)
COPD	M	>15 yo	Ia	1.9 (1.15 to 3.13)
Lung Cancer (coal)	F	> 15 yr	Ia	1.98 (1.16 to 3.36)
Lung Cancer (coal)	M	> 15 yr	Ia*	1.38
Cataract	F	> 30 yr	Ia	2.45 (1.61 to 3.73)
Cataract	M	> 30 yr	Ia	?
LBW (OR)	M & F	Perinatal	Ia	1.52 (1.25 to 1.80)
LBW (mean weight)	M & F	Perinatal	Ia	93.1g (64.6, 121.6)
Lung Cancer (biomass)	F	> 15 yr	Ia	1.81 (1.07 to 3.06)
Lung Cancer (biomass)	M	> 15 yr	Ia	1.26 (1.04 to 1.52)
CVD	F	> 30 yr	Ib	1.3 to 1.4 (95% CI)
CVD	M	> 30 yr	Ib*	1.16

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

RESPIRE Results

(Randomized Exposure Study of Pollution Indoors and Respiratory Effects)

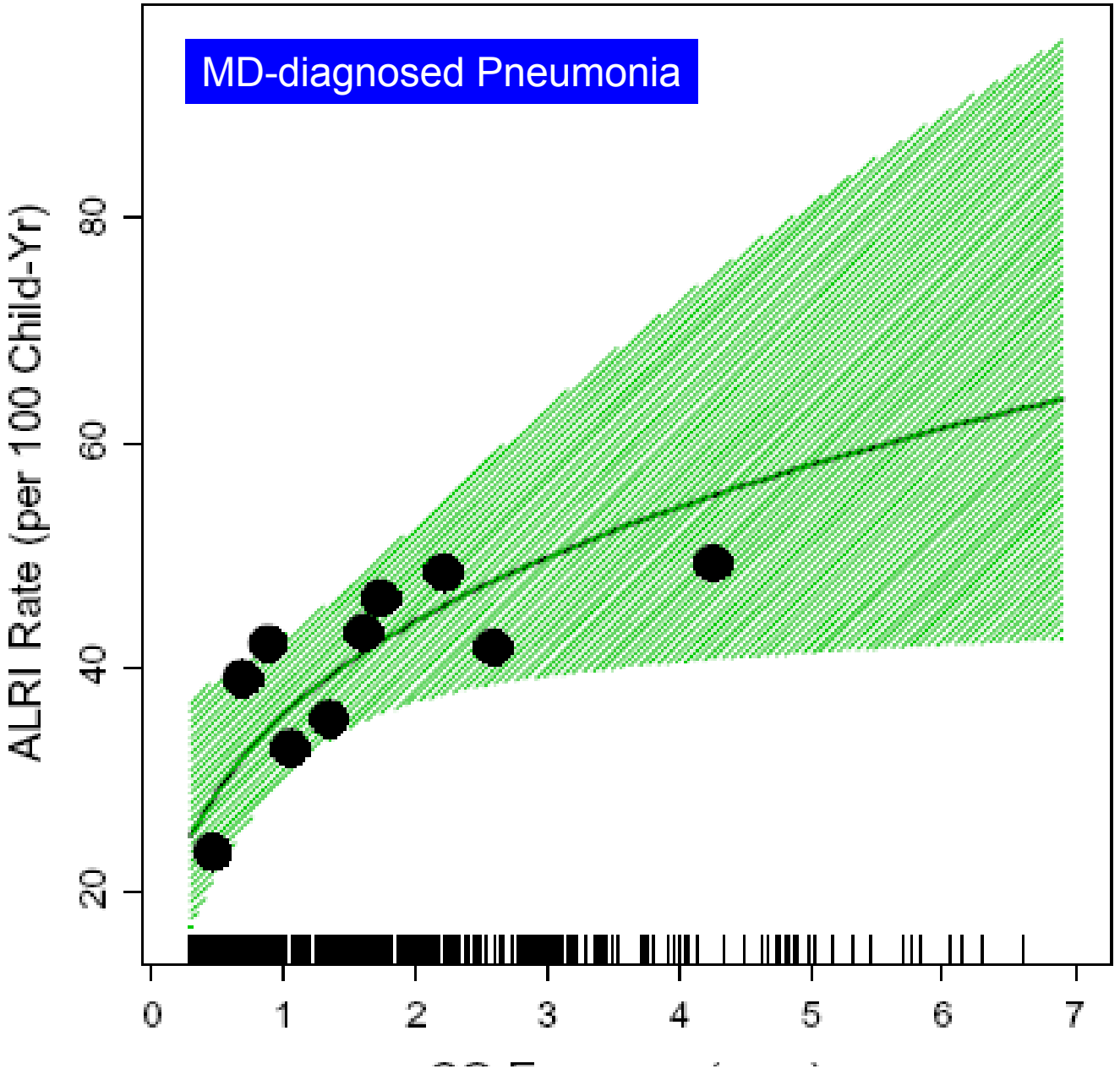
- Intention-to-Treat analysis of the RCT under journal embargo
- Will present preliminary results of the exposure-response analysis, which is most relevant to this audience


Tubito
Tubito

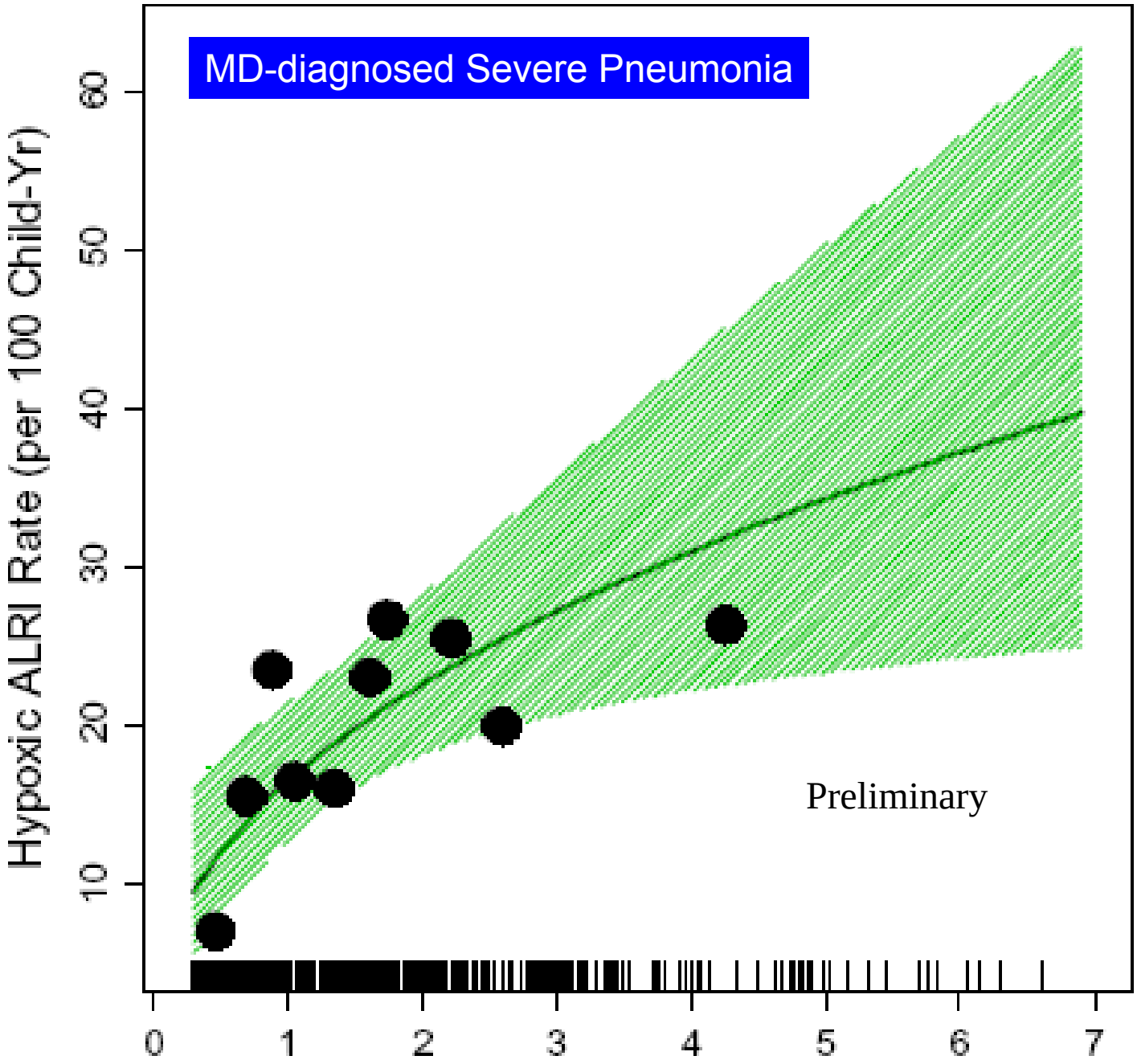
Preliminary Adjustments for Exposure-Response Model

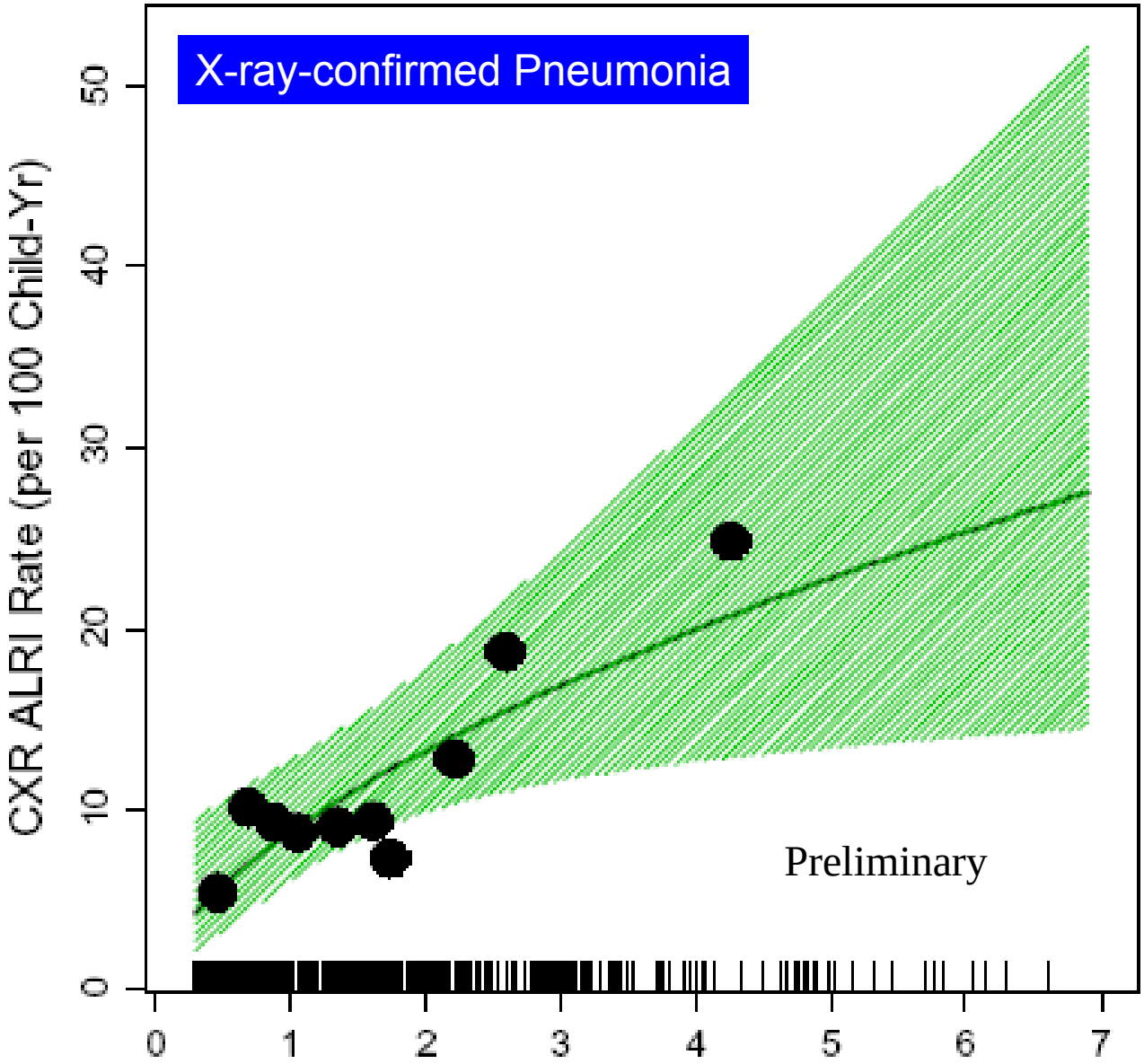
- Adjusted for child's age (quadratic), sex, birth interval less than 2 yr (yes/no), mother's age (quadratic), maternal education and paternal education (none/primary/ secondary), secondhand tobacco smoke exposure (yes/no), latrine (yes/no), piped water (yes/no), electricity (yes/no), kerosene lamp (yes/no), 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).

Preliminary

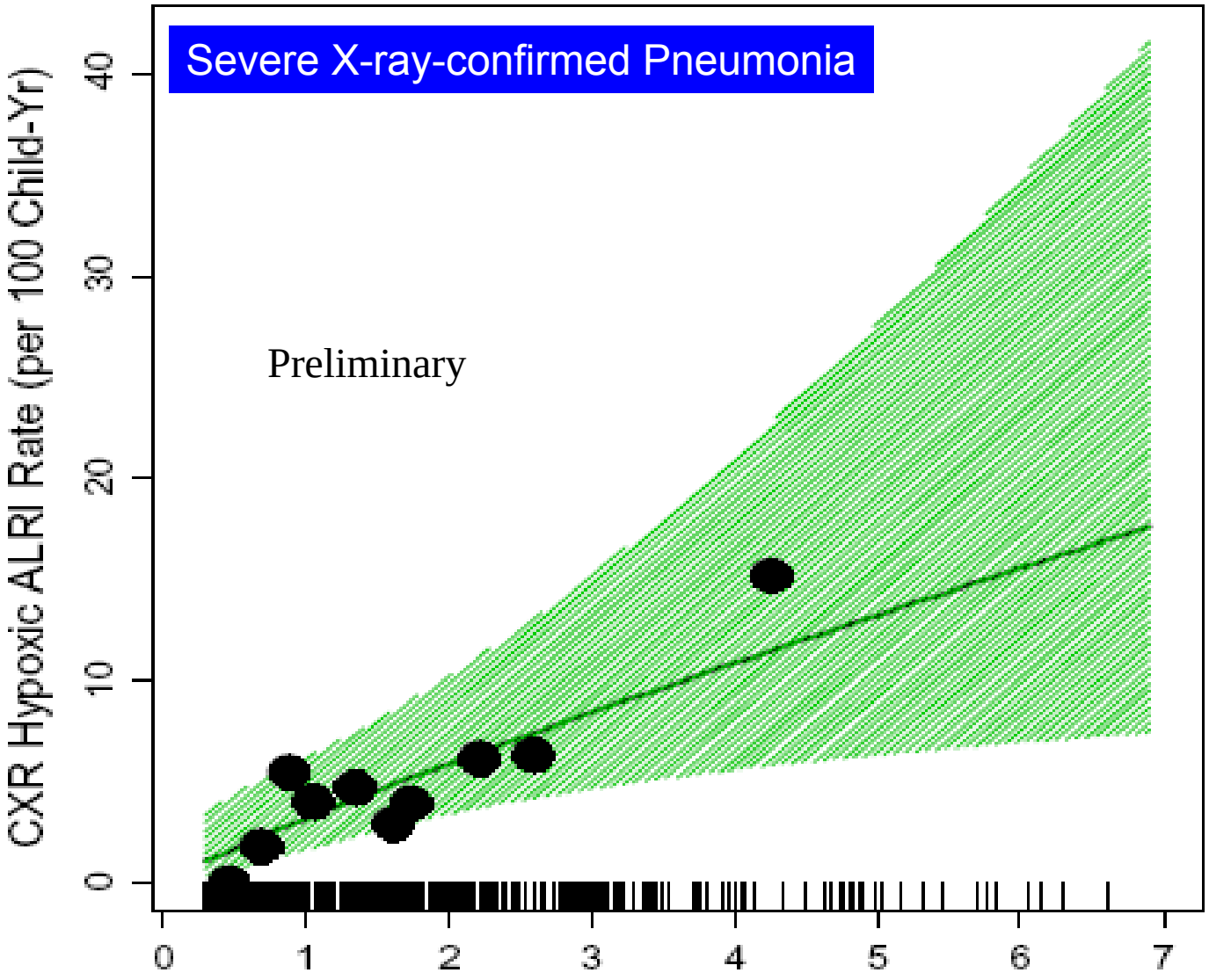


Approximate Mean PM2.5 exposure in 100s of ug/m3


MD-diagnosed Severe Pneumonia
Hypoxic ALRI Rate (per 100 Child-Yr)
10
20
30
40
50
60
0
1
2
3
4
5
6
7
Preliminary
Approximate Mean PM2.5 exposure in 100s of µg/m3



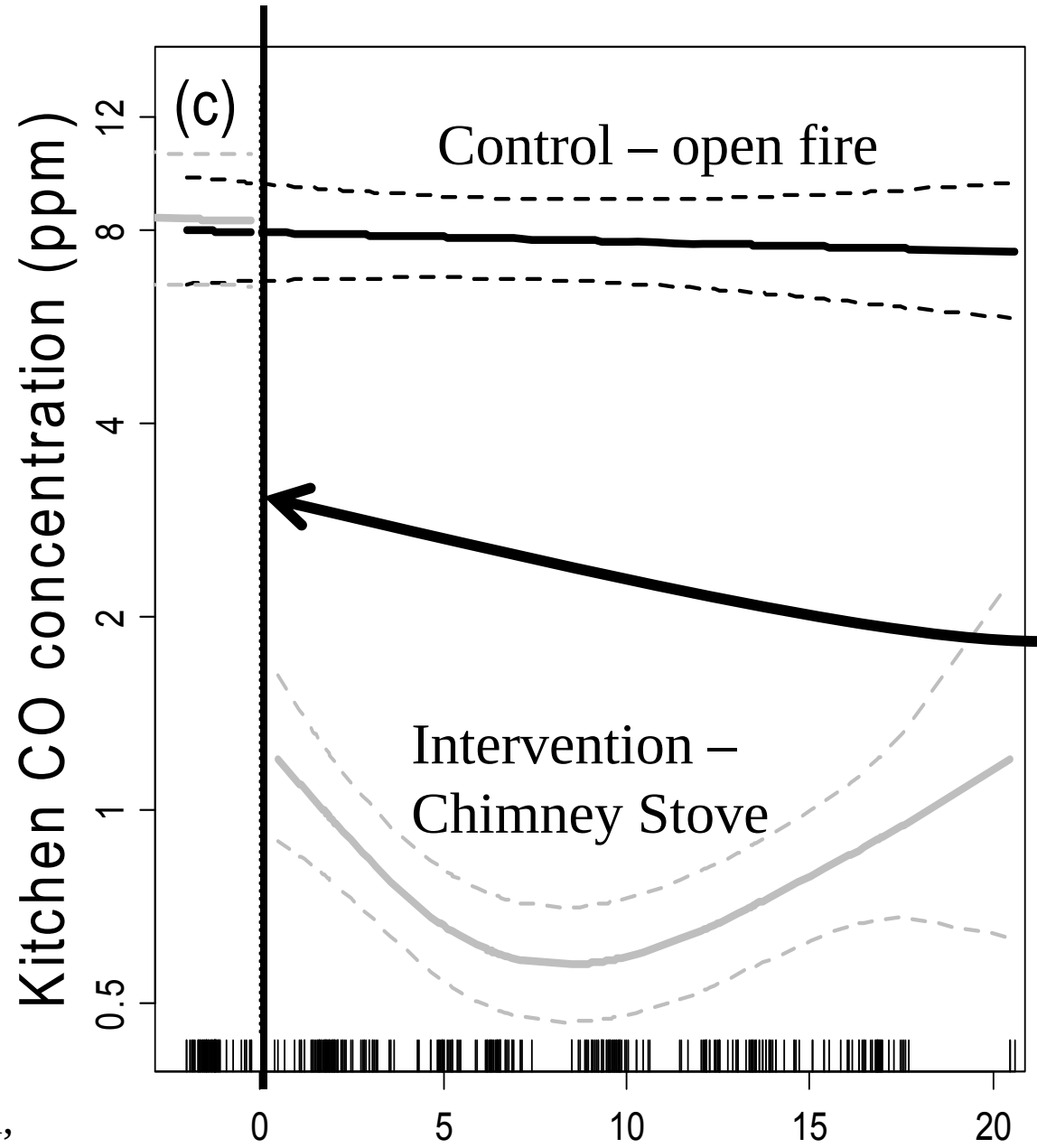
Approximate Mean PM2.5 exposure in 100s of ug/m3


Severe X-ray-confirmed Pneumonia
Preliminary
CXR Hypoxic ALRI Rate (per 100 Child-Yr)
0
10
20
30
40
0
1
2
3
4
5
6
7
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



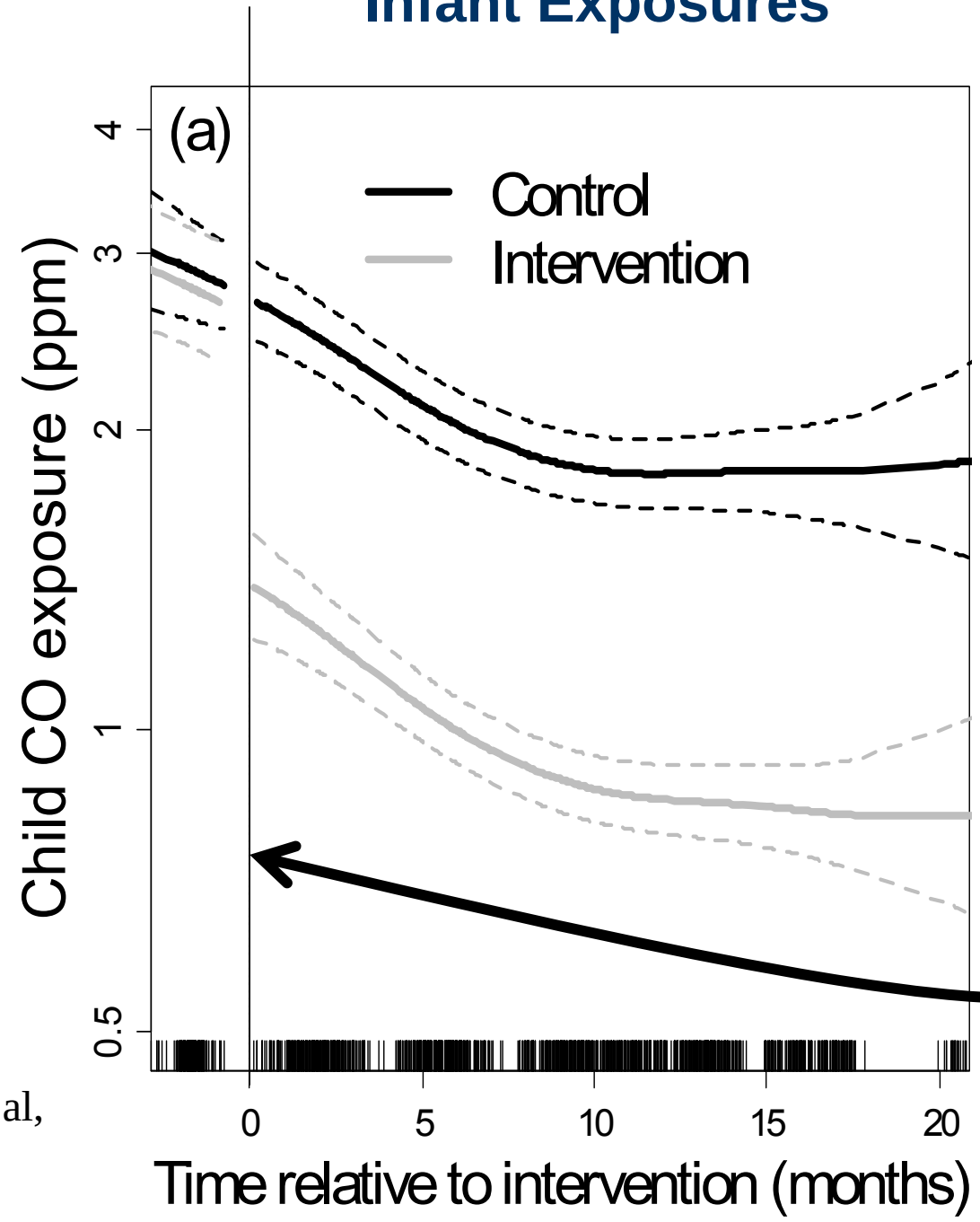
Effect of Chimney Stove On Kitchen CO Levels

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

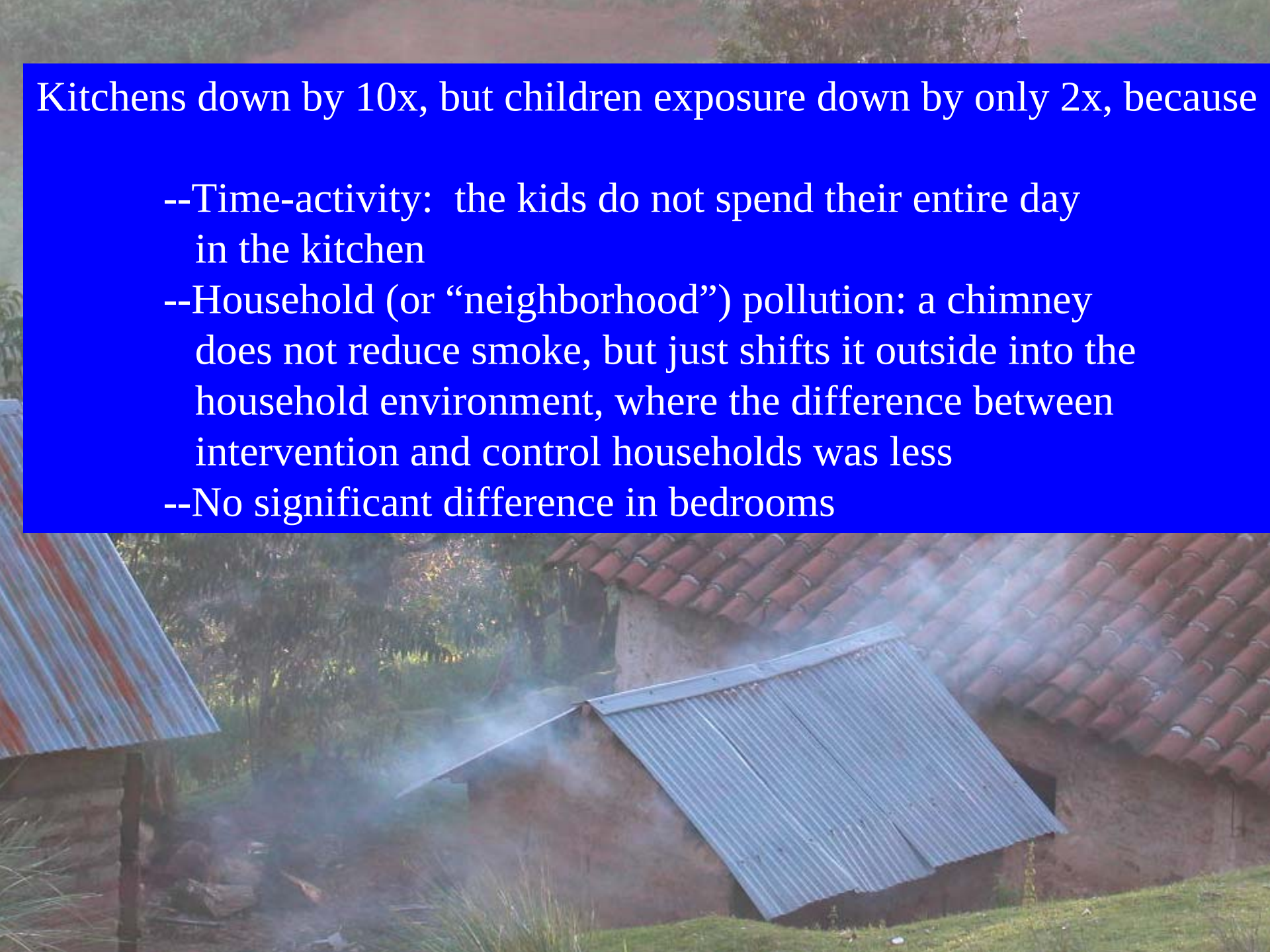
Smith, et al, 2010

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

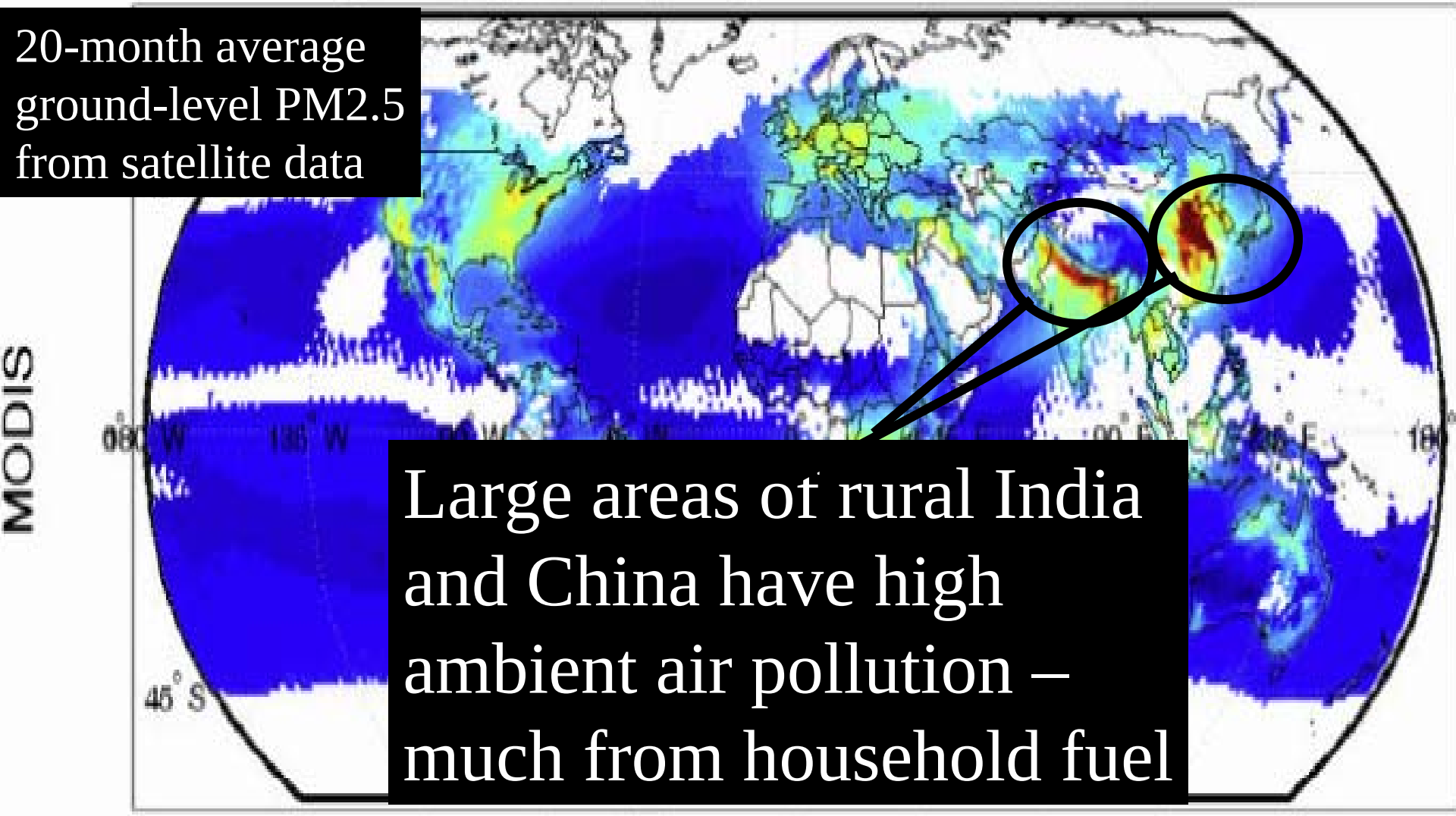
--Time-activity: the kids do not spend their entire day in the kitchen

--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

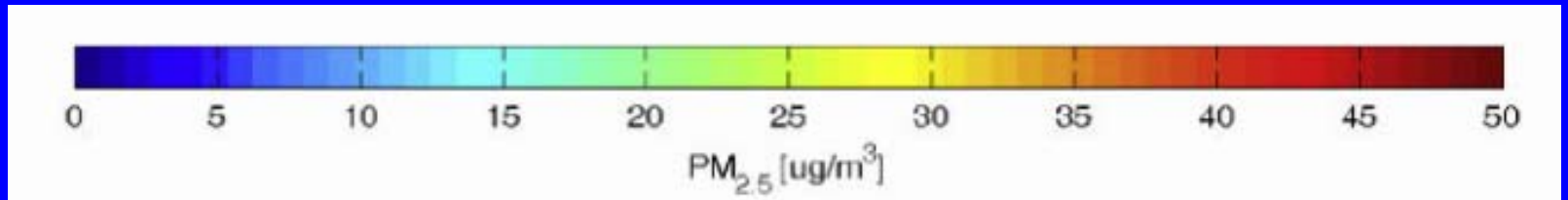
--No significant difference in bedrooms



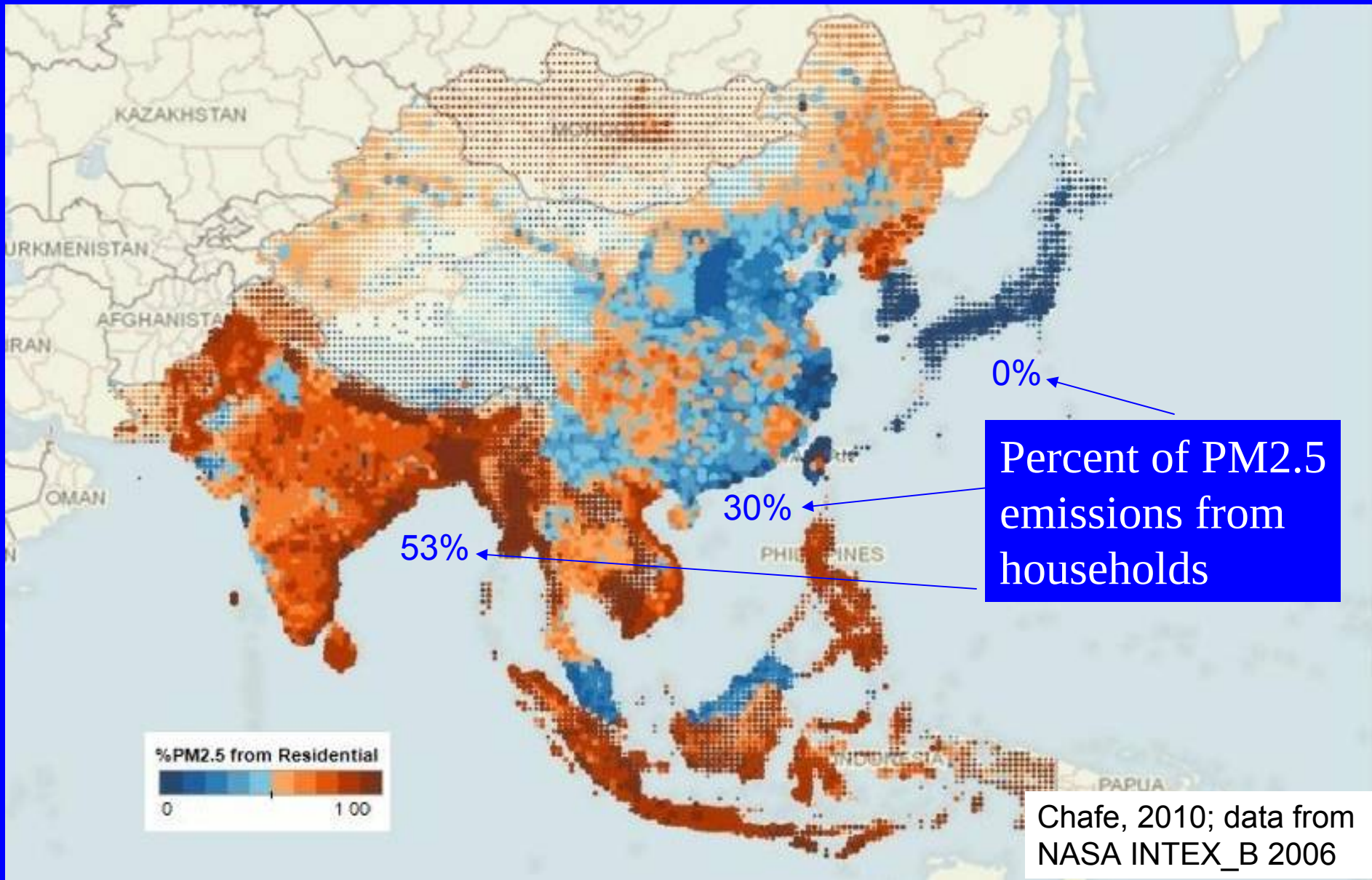
20-month average ground-level PM2.5 from satellite data



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

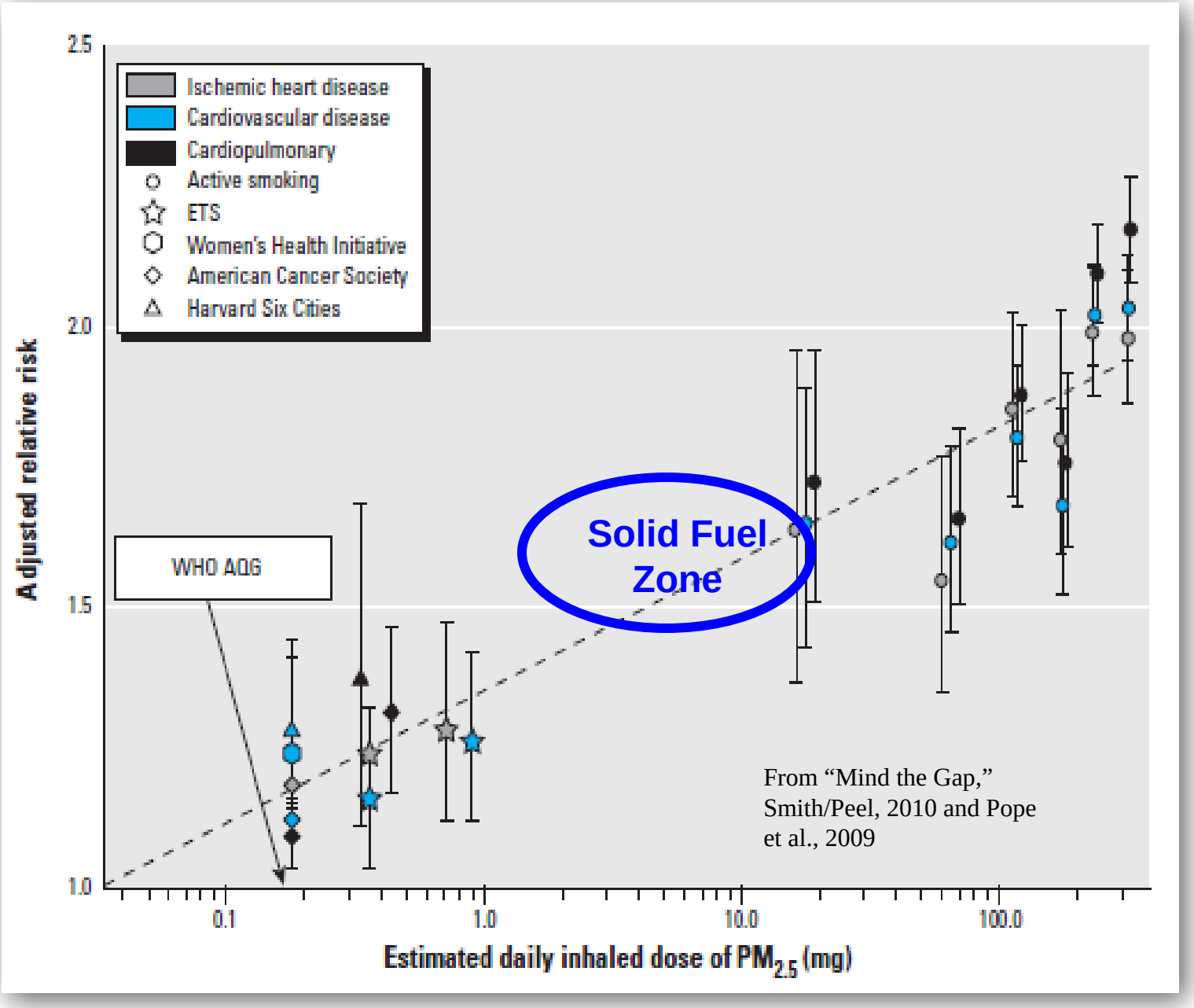


NASA INTEX_B Database
Percent $PM_{2.5}$ emissions from households



Chafe, 2010; data from NASA INTEX_B 2006

Heart Disease and Combustion Particle Doses

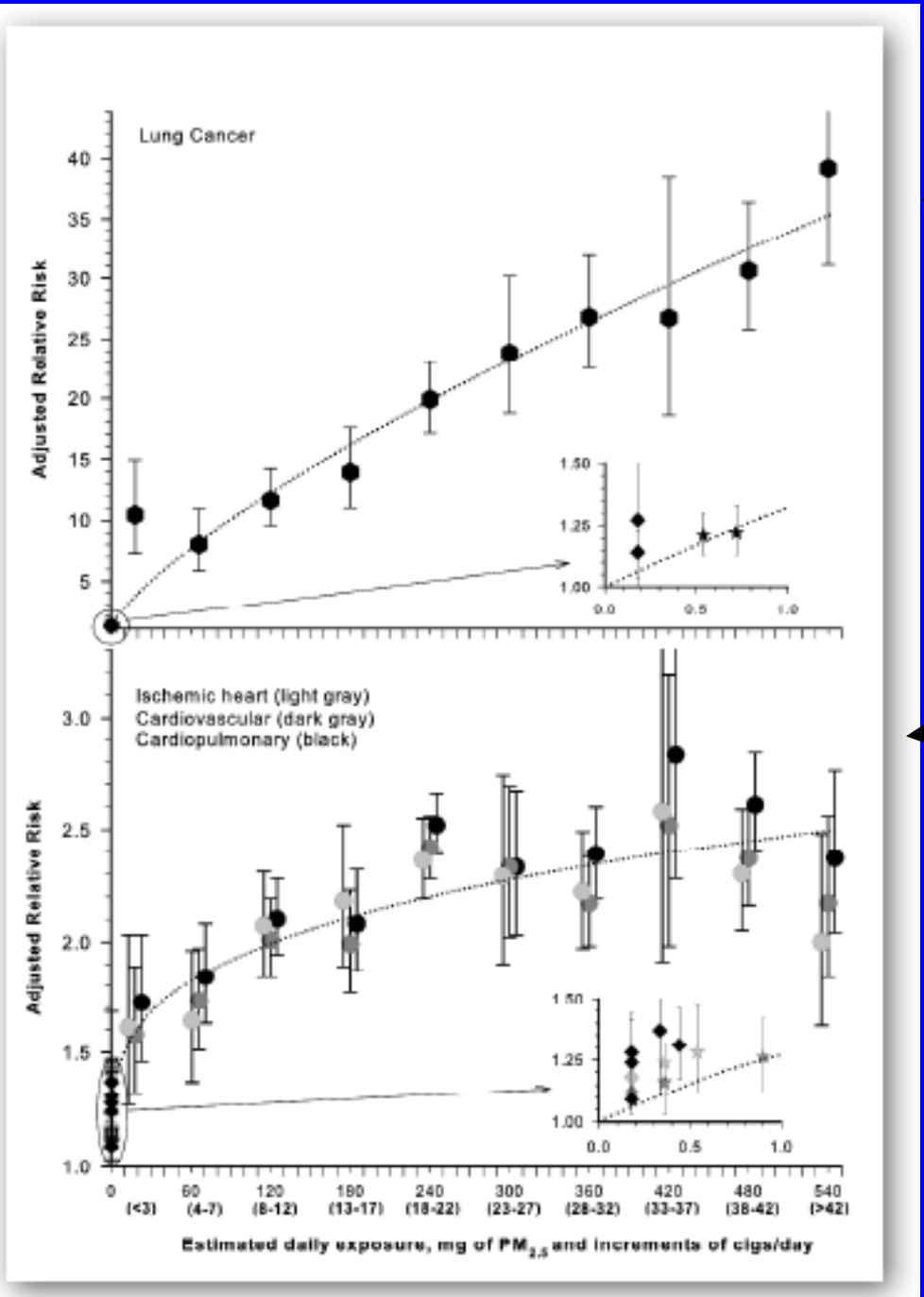


From "Mind the Gap," Smith/Peel, 2010 and Pope et al., 2009

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

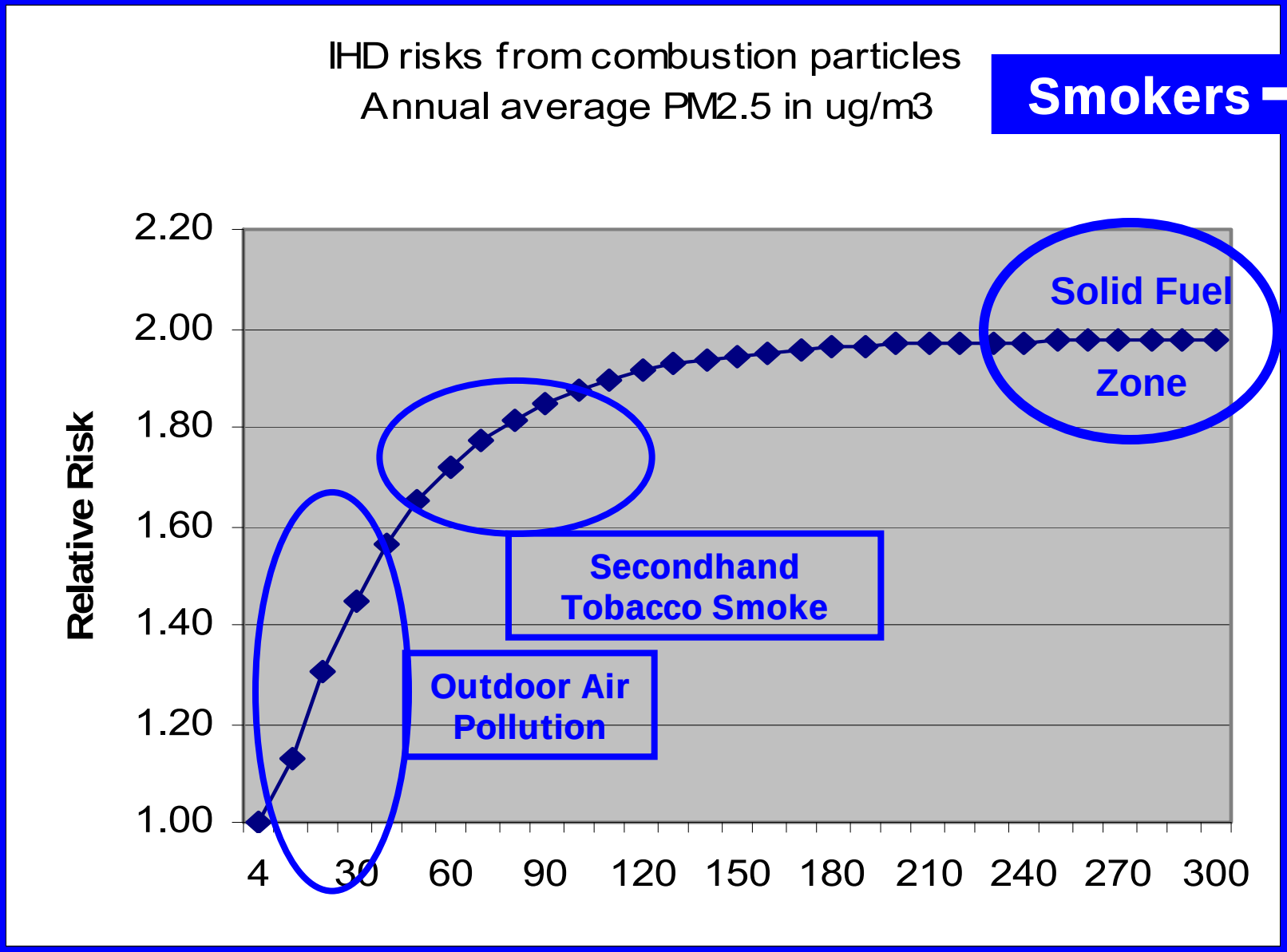


Lung Cancer

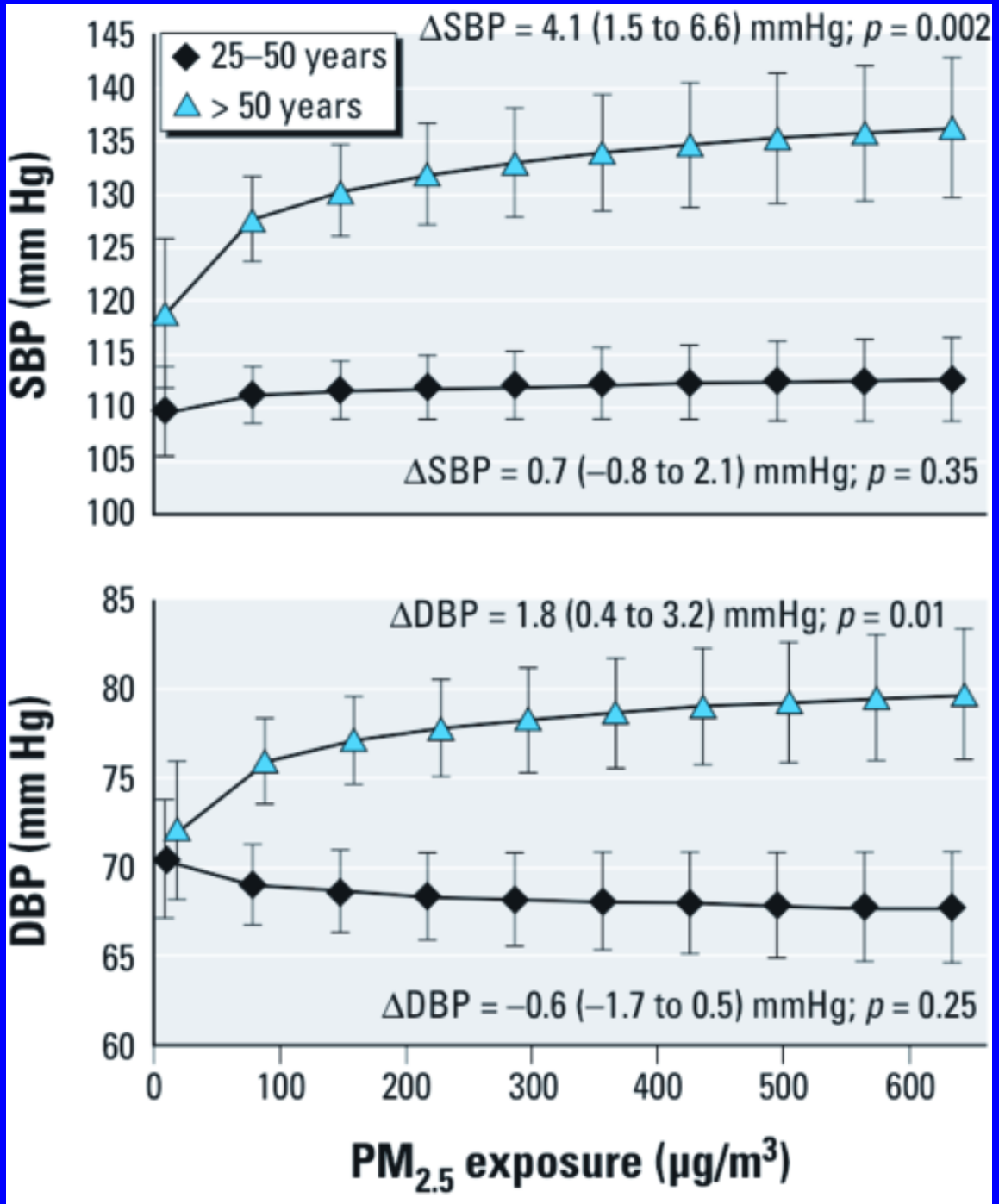
Heart Disease

Pope et al. Environmental Health Perspectives 2011, in press

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



CRA, 2011

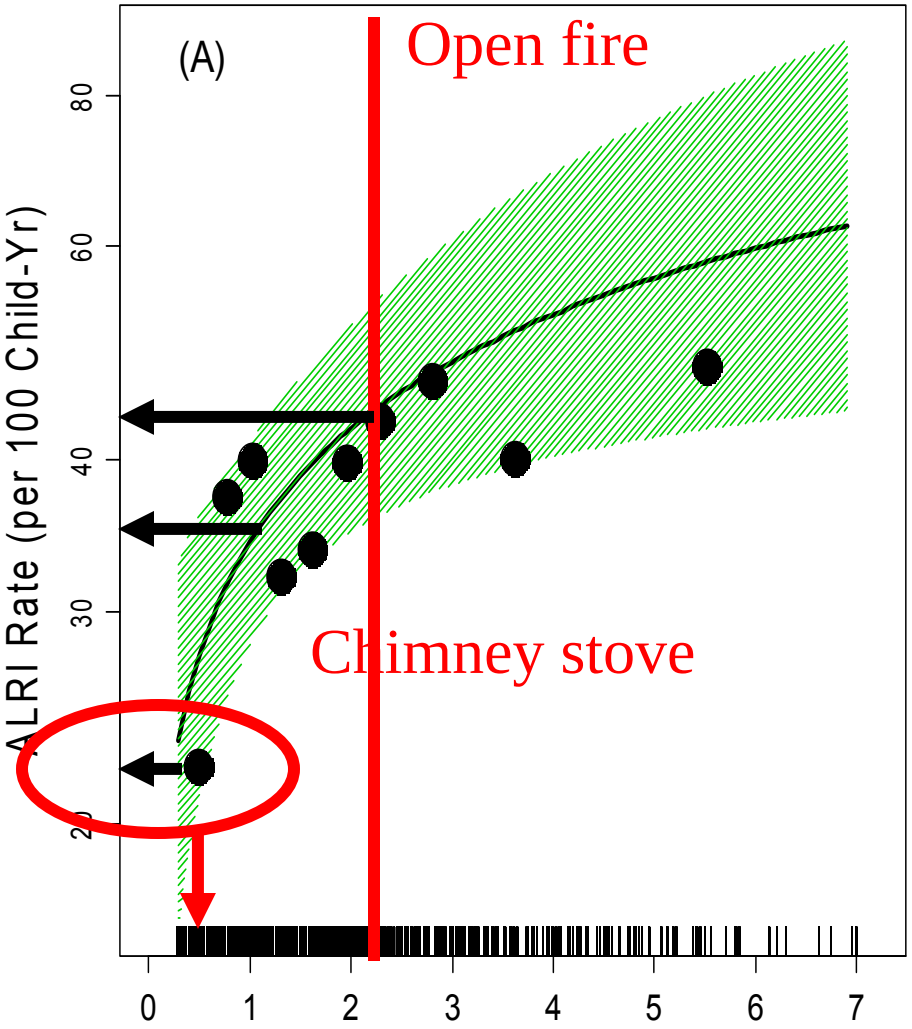


Household Air Pollution and Blood Pressure

In Yunnan

Baumgartner et al. Environmental Health Perspectives 2011, Oct

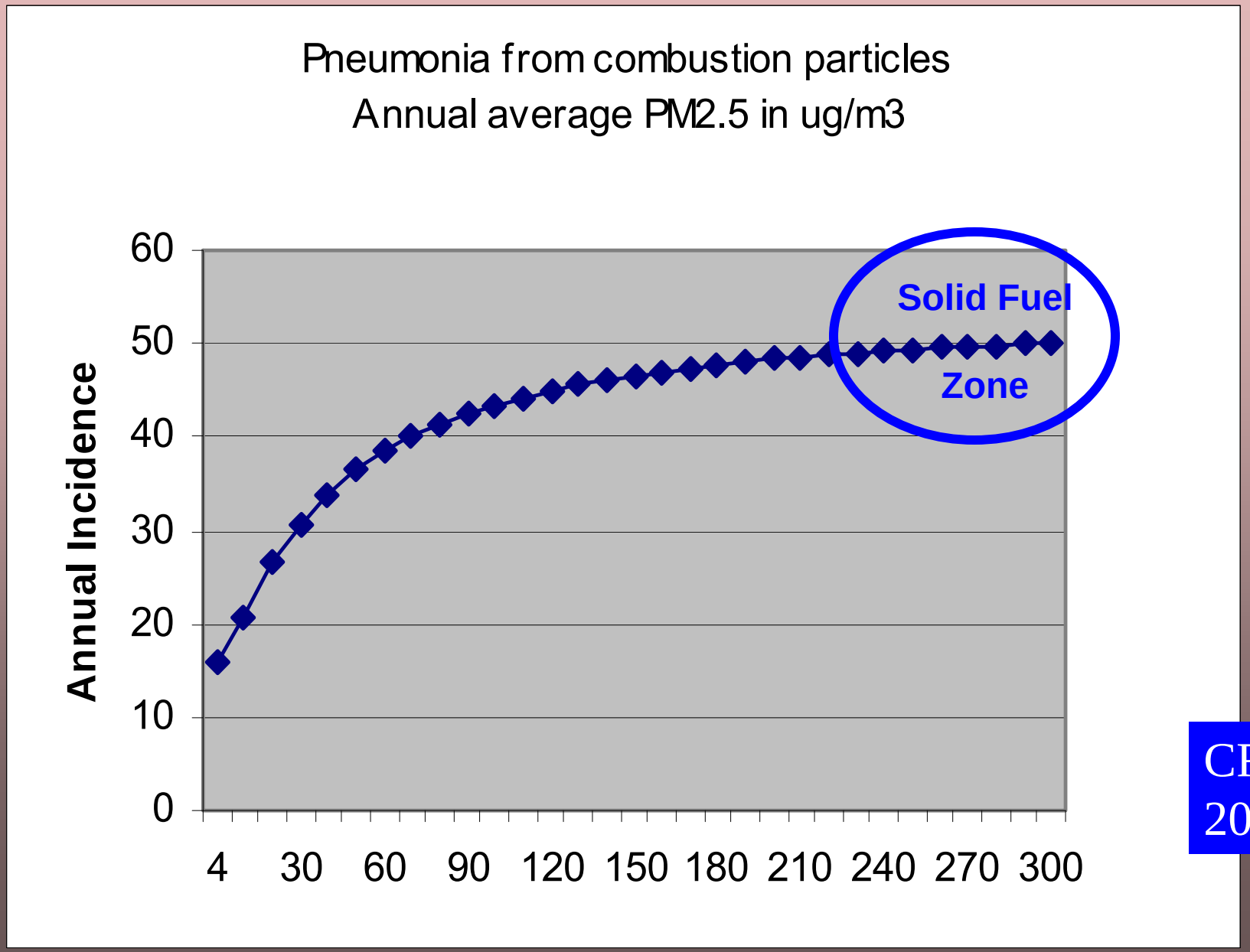
MD-diagnosed Acute Lower Respiratory Infection



Where we Want to Be!

RESPIRE-Guatemala

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



CRA, 2011

Lessons

- We call it household, not indoor, air pollution because effects occur at all scales, from next to the stove to the planet
- Only way to reduce the effects to improved combustion – not produce pollution in first place (chimneys are not enough)
- Coal is not possible to burn cleanly – need to move to low emissions fuels.
- All coal should be eliminated in household use

Many thanks

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