Global and South Asian Burdens of Disease from Household Air Pollution: the GBD 2010 Study

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- With much help from Majid Ezzati, Imperial/GBD; and Aaron Cohen, HEI

Definitions

- **Global Burden of Disease (GBD)**
- Envelope of death, illness, and injury by age, sex, and region.
- Coherent – no overlap – one death has one cause

- **Comparative Risk Assessment (CRA)**
- The amount of the GBD due to a particular risk factor, e.g. smoking
- Not coherent – deaths can be prevented by several means

GBD 2010

- The global burden of diseases, injuries, and risk factors 2010 (GBD) Study examines 3 major disease groups (communicable diseases, non-communicable diseases and injuries), with 1045 specific outcomes/sequelae of 235 causes of death.
- 21 regions
- 1990 and 2010
- 20 age groups.
- Associated CRA addresses more than 60 risk factors, including household air pollution

GBD 2010

- Involves hundreds of experts working on epidemiology and exposures related to specific diseases, injuries, and risk factors
- Core group brings the pieces together in common analytical frameworks.
- Coordinated by the Institute for Health Metrics and Evaluation at the University of Washington.
- Unlike previous efforts, the WHO was not involved in the core group at the end

Metrics

- Mortality – important, but can be misleading as it does not take age into account or years of illness/injury
  - Death at 88 years counts same as at 18, which is not appropriate
- Disability-adjusted Life Years (DALYs) lost do account for age and illness.
- GBD 2010 compares deaths against best life expectancy in world – 86 years
- Much improved method for determining severity weights for diseases and injuries

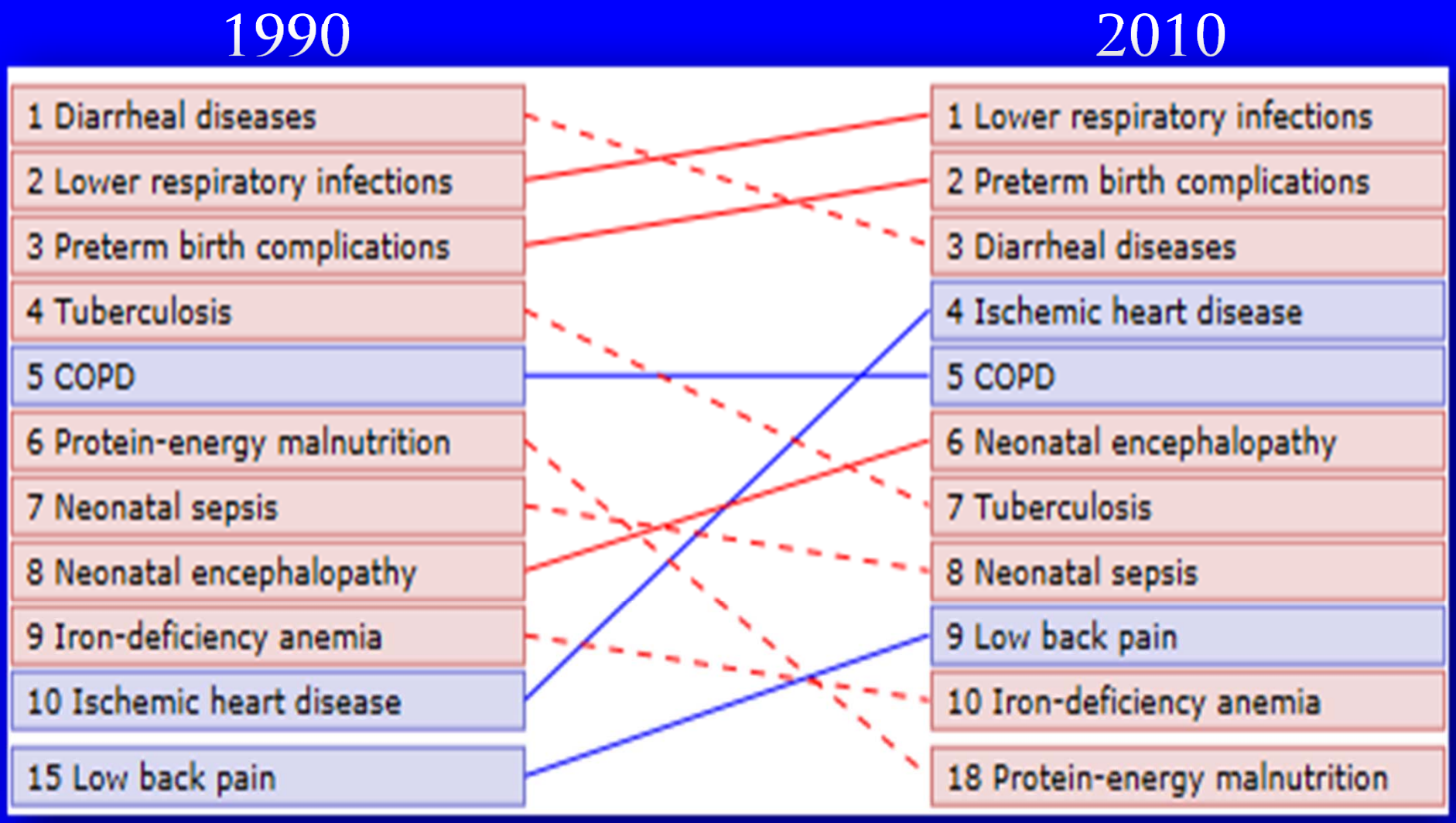
Leading causes of global disease burden, 1990 and 2010

1990 Mean rank (95% UI)	1990 Disorder	2010 Disorder	2010 Mean rank (95% UI)	2010 % change (95% UI)
1·0 (1 to 2)	1 Lower respiratory infections	1 Ischaemic heart disease	1·0 (1 to 2)	29 (22 to 34)
2·0 (1 to 2)	2 Diarrhoea	2 Lower respiratory infections	2·0 (1 to 3)	–44 (–48 to –39)
3·4 (3 to 5)	3 Preterm birth complications	3 Stroke	3·2 (2 to 5)	19 (5 to 26)
3·8 (3 to 5)	4 Ischaemic heart disease	4 Diarrhoea	4·9 (4 to 8)	–51 (–57 to –45)
5·2 (4 to 6)	5 Stroke	5 HIV/AIDS	6·6 (4 to 9)	351 (293 to 413)
6·3 (5 to 8)	6 COPD	6 Low back pain	6·7 (3 to 11)	43 (34 to 53)
8·0 (6 to 13)	7 Malaria	7 Malaria	6·7 (3 to 11)	21 (–9 to 63)
9·9 (7 to 13)	8 Tuberculosis	8 Preterm birth complications	8·0 (5 to 11)	–27 (–37 to –16)
10·2 (7 to 14)	9 Protein–energy malnutrition	9 COPD	8·1 (5 to 11)	–2 (–8 to 5)
10·3 (7 to 15)	10 Neonatal encephalopathy*	10 Road injury	8·4 (4 to 11)	34 (11 to 63)
11·3 (7 to 17)	11 Low back pain	11 Major depressive disorder	10·8 (7 to 14)	37 (25 to 50)
11·8 (8 to 15)	12 Road injury	12 Neonatal encephalopathy*	13·3 (11 to 17)	–17 (–30 to –1)
12·9 (8 to 16)	13 Congenital anomalies	13 Tuberculosis	13·4 (11 to 17)	–19 (–34 to –6)
15·0 (8 to 18)	14 Iron-deficiency anaemia	14 Diabetes	14·2 (12 to 16)	69 (58 to 77)
15·2 (11 to 18)	15 Major depressive disorder	15 Iron-deficiency anaemia	15·2 (11 to 22)	–3 (–6 to –1)
15·3 (3 to 36)	16 Measles	16 Neonatal sepsis	15·9 (10 to 26)	–3 (–25 to 27)
15·4 (8 to 24)	17 Neonatal sepsis	17 Congenital anomalies	17·3 (14 to 21)	–28 (–43 to –9)
17·3 (15 to 19)	18 Meningitis	18 Self-harm	18·8 (15 to 26)	24 (0 to 42)
20·0 (17 to 26)	19 Self-harm	19 Falls	19·7 (16 to 25)	37 (20 to 55)
20·7 (18 to 26)	20 Drowning	20 Protein–energy malnutrition	20·0 (16 to 26)	–42 (–51 to –33)
21·1 (18 to 25)	21 Diabetes	21 Neck pain	21·1 (14 to 28)	41 (28 to 55)
23·1 (19 to 28)	22 Falls	22 Lung cancer	21·8 (17 to 27)	36 (18 to 47)
24·1 (21 to 30)	23 Cirrhosis	23 Cirrhosis	23·0 (19 to 27)	28 (19 to 36)
25·1 (20 to 32)	24 Lung cancer	24 Other musculoskeletal disorders	23·1 (19 to 26)	50 (43 to 57)
25·3 (18 to 34)	25 Neck pain	25 Meningitis	24·4 (20 to 27)	–22 (–32 to –12)
	29 Other musculoskeletal disorders	32 Drowning		
	33 HIV/AIDS	56 Measles		

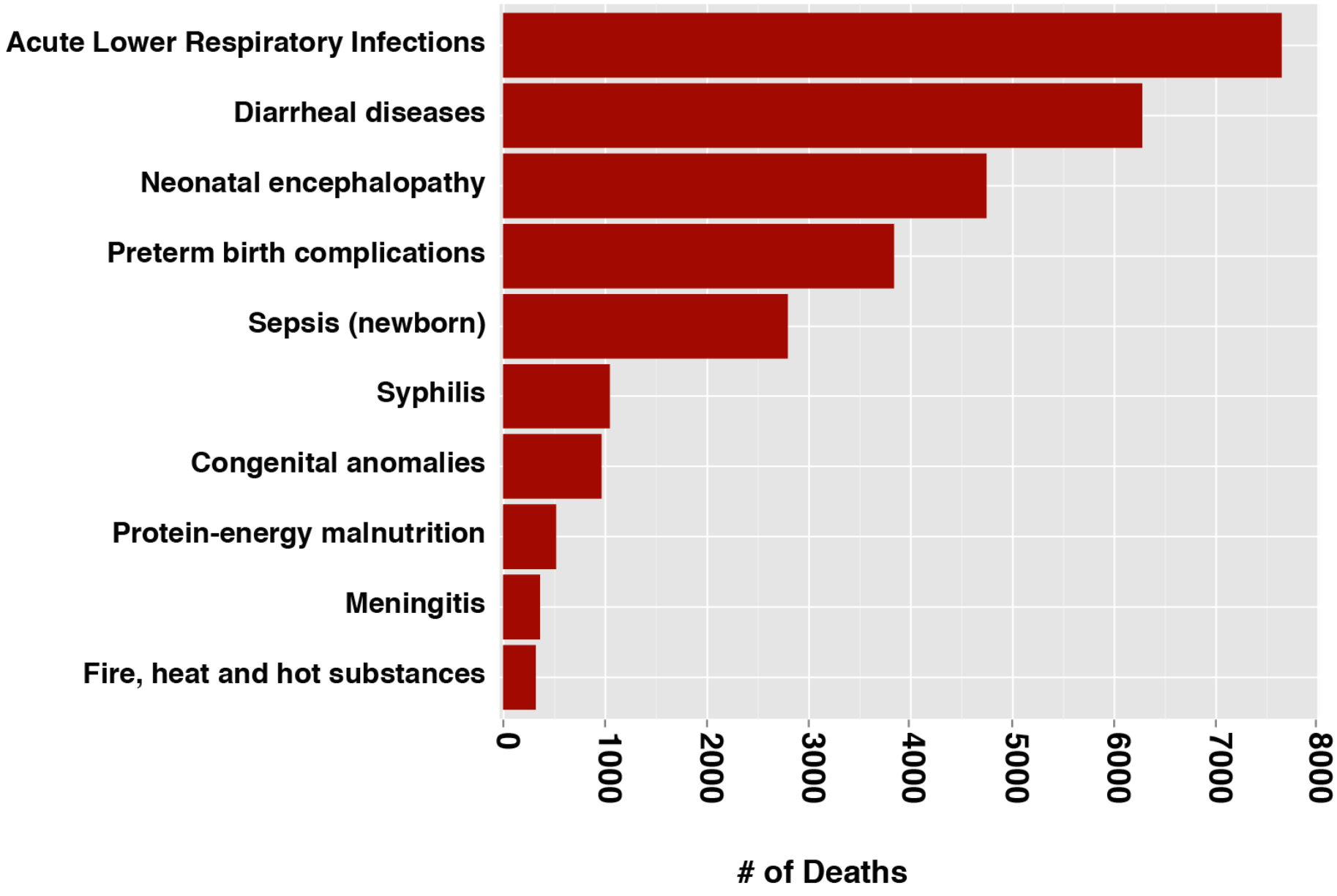
Communicable, maternal, neonatal, and nutritional disorders
Non-communicable diseases
Injuries

—— Ascending order in rank
- - - - Descending order in rank

DALYs, South Asia, by Disease



Under 5 Deaths by Cause (Nepal, 2010)



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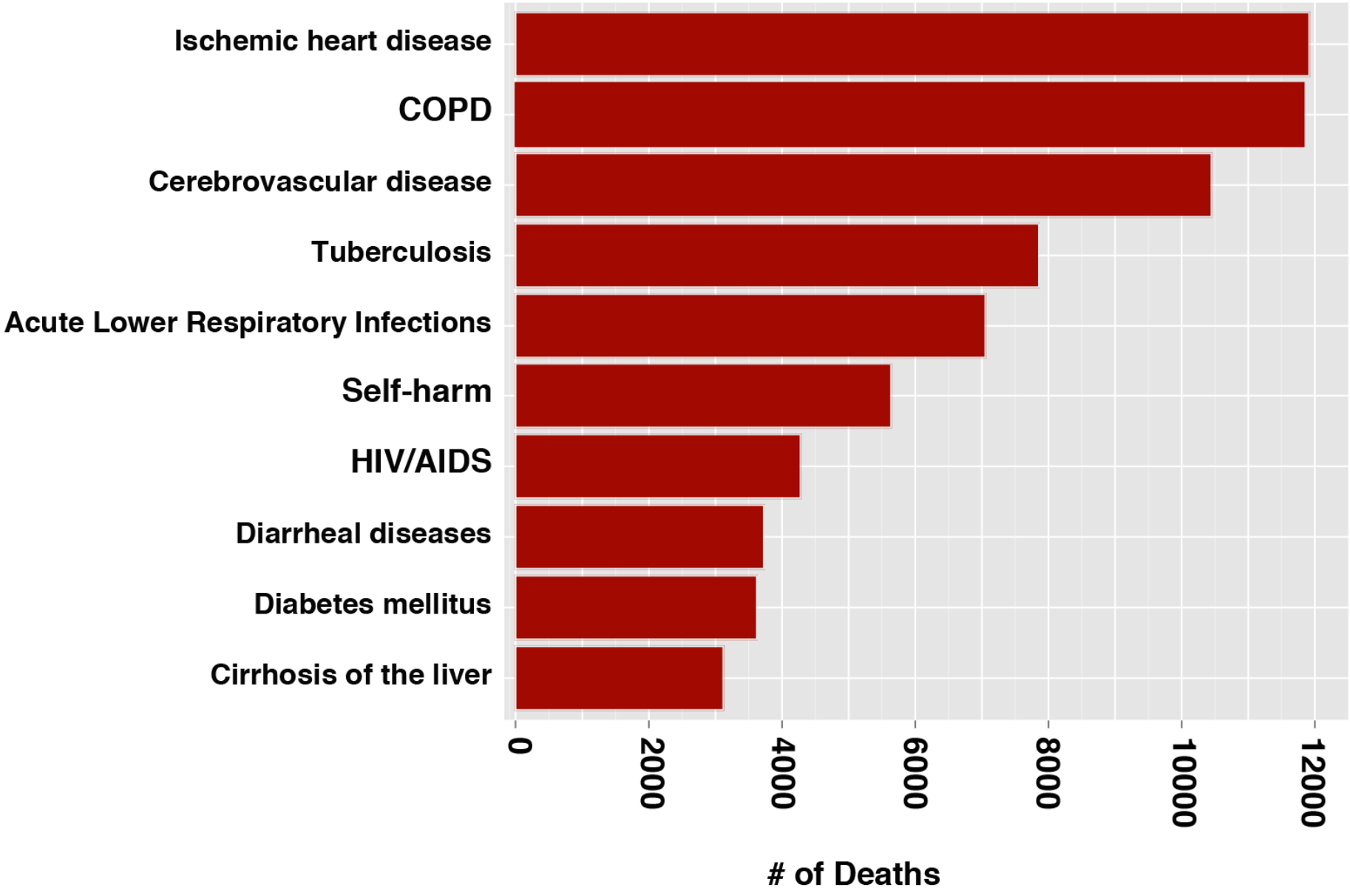


A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010

Stephen S Lim‡, Theo Vos, Abraham D Flaxman, Goodarz Danaei, Kenji Shibuya, Heather Adair-Rohani*, Markus Amann*, H Ross Anderson*, Kathryn G Andrews*, Martin Aryee*, Charles Atkinson*, Loraine J Bacchus*, Adil N Bahalim*, Kalpana Balakrishnan*, John Balmes*, Suzanne Barker-Collo*, Amanda Baxter*, Michelle L Bell*, Jed D Blore*, Fiona Blyth*, Carissa Bonner*, Guilherme Borges*, Rupert Bourne*, Michel Boussinesq*, Michael Brauer*, Peter Brooks*, Nigel G Bruce*, Bert Brunekreef*, Claire Bryan-Hancock*, Chiara Bucello*, Rachelle Buchbinder*, Fiona Bull*, Richard T Burnett*, Tim E Byers*, Bianca Calabria*, Jonathan Carapetis*, Emily Carnahan*, Zoe Chafe*, Fiona Charlson*, Honglei Chen*, Jian Shen Chen*, Andrew Tai-Ann Cheng*, Jennifer Christine Child*, Aaron Cohen*, K Ellicott Colson*, Benjamin C Cowie*, Sarah Darby*, Susan Darling*, Adrian Davis*, Louisa Degenhardt*, Frank Dentener*, Don C Des Jarlais*, Karen Devries*, Mukesh Dherani*, Eric L Ding*, E Ray Dorsey*, Tim Driscoll*, Karen Edmond*, Suad Eltahir Ali*, Rebecca E Engell*, Patricia J Erwin*, Saman Fahimi*, Gail Falder*, Farshad Farzadfar*,

CRA published along with the other
GBD papers on Dec 14, 2012
in *The Lancet*

CRA of the GBD 2010 – risks quantified

Unimproved water and sanitation

Unimproved water

Unimproved sanitation

Air pollution

Ambient particulate matter pollution

Household air pollution from solid fuels

- Second-hand cooksmoke

Ambient ozone pollution

Other environmental risks

Residential radon

Lead exposure

Child and maternal undernutrition

Suboptimal breastfeeding

- Non-exclusive breastfeeding
- Discontinued breastfeeding

Childhood underweight

Iron deficiency

Vitamin A deficiency

Zinc deficiency

Tobacco smoking and secondhand smoke

Tobacco smoking

Second-hand smoke

Alcohol and other drugs

Alcohol use

Drug use (opioids, cannabis, amphetamines)

Physiological risks for chronic diseases

High fasting plasma glucose

High total cholesterol

High systolic blood pressure

High body mass index

Low bone mineral density

Sexual abuse and violence

Childhood sexual abuse

Intimate partner violence

CRA of the GBD 2010 – (cont)

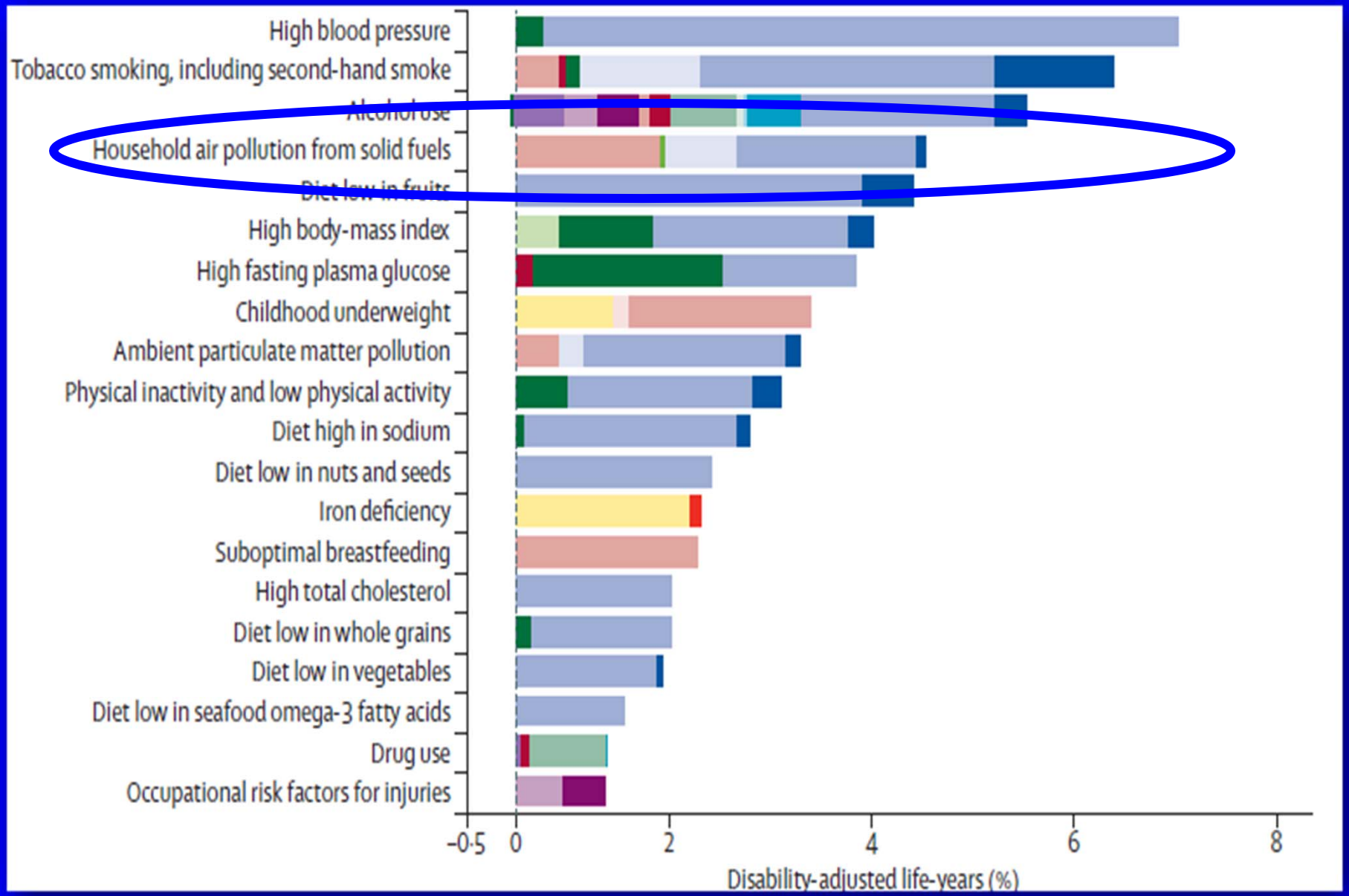
Dietary risk factors and physical inactivity

Diet low in fruits
Diet low in vegetables
Diet low in whole grains
Diet low in nuts/seeds
Diet low in milk
Diet high in unprocessed red meat
Diet high in processed meat
Sugar-sweetened beverages
Diet low in fibre
Diet low in calcium
Diet low in seafood omega-3
Diet low in polyunsaturated fatty acid (PUFA)
Diet high in trans fatty acids
Diet high in sodium
Physical inactivity and low physical activity

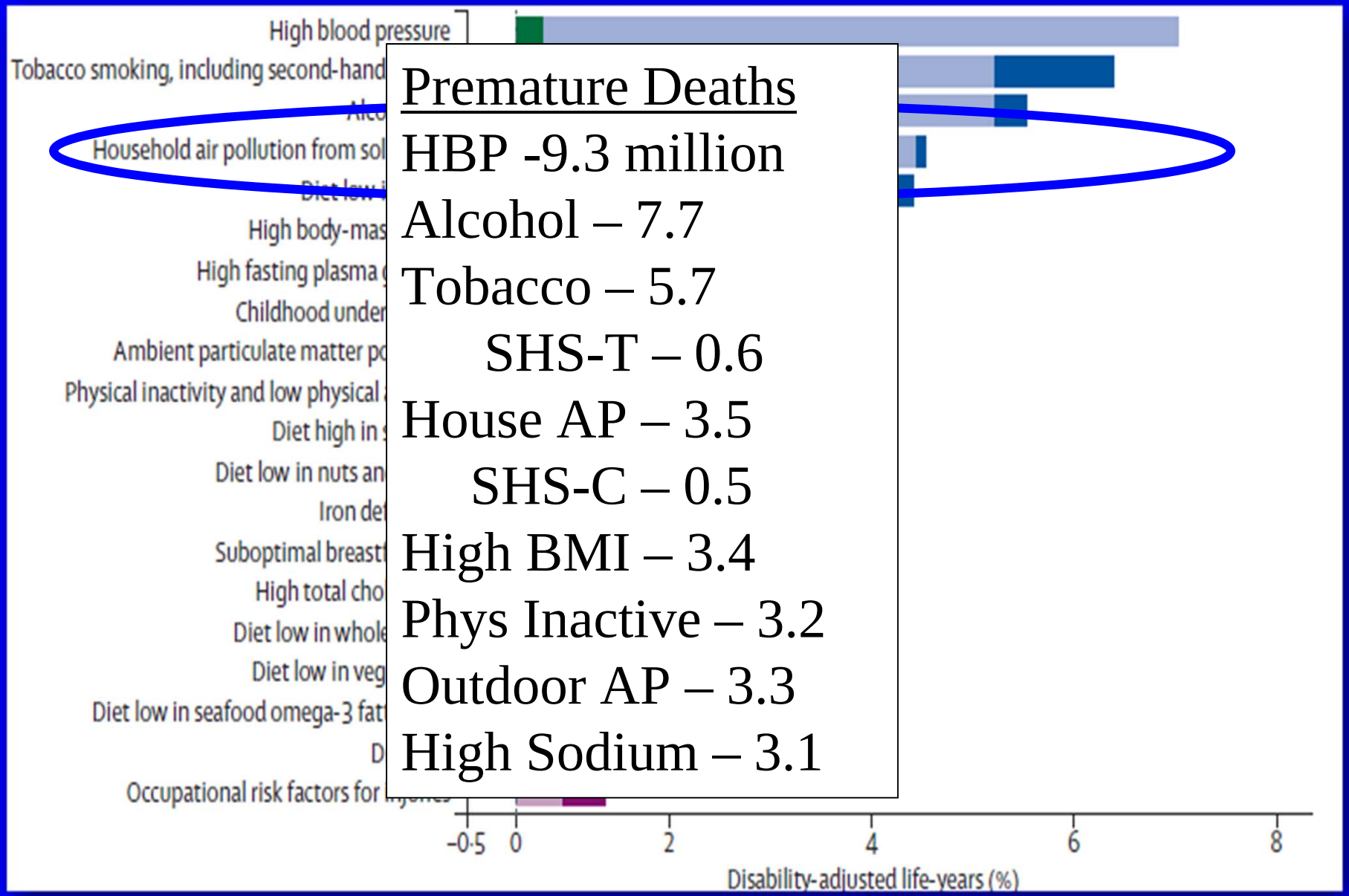
Occupational exposures

Occupational exposure to asbestos
Occupational exposure to arsenic
Occupational exposure to benzene
Occupational exposure to beryllium
Occupational exposure to cadmium
Occupational exposure to chromium
Occupational exposure to diesel
Occupational exposure to formaldehyde
Occupational exposure to nickel
Occupational exposure to PAHs
Occupational exposure to secondhand smoke
Occupational exposure to silica
Occupational exposure to sulfuric acid
Occupational exposure to asthmagens
Occupational exposure to particulates and gases
Occupational noise
Occupational risk factors for injury
Occupational low back pain

Global DALYs 2010: Top 20 Risk Factors



Global DALYs 2010: Top 20 Risk Factors



Premature Deaths

HBP -9.3 million

Alcohol – 7.7

Tobacco – 5.7

SHS-T – 0.6

House AP – 3.5

SHS-C – 0.5

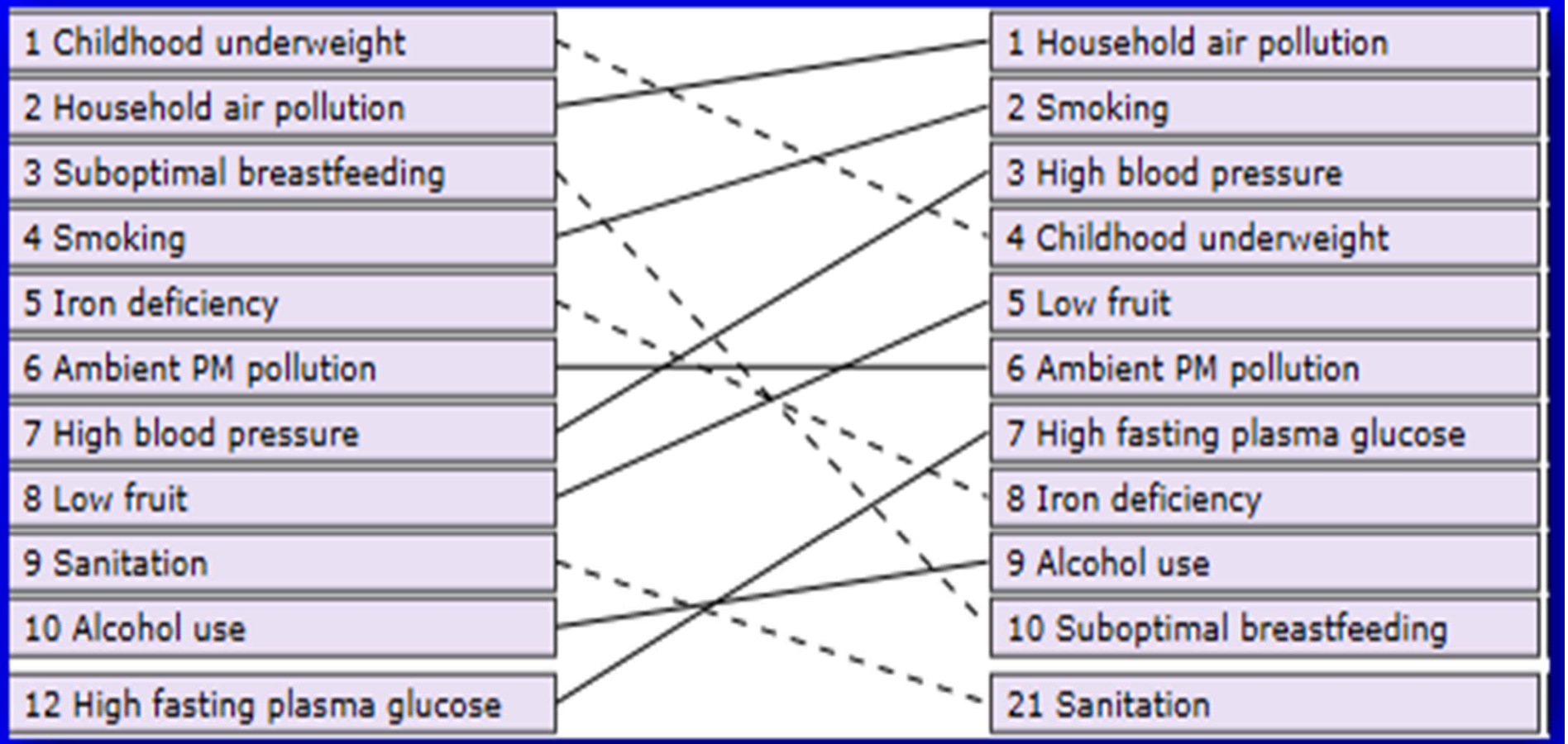
High BMI – 3.4

Phys Inactive – 3.2

Outdoor AP – 3.3

High Sodium – 3.1

DALYS. South Asia by Risk Factor



HAP in India in 2010

~900 thousand annual premature deaths

About one-quarter of global total

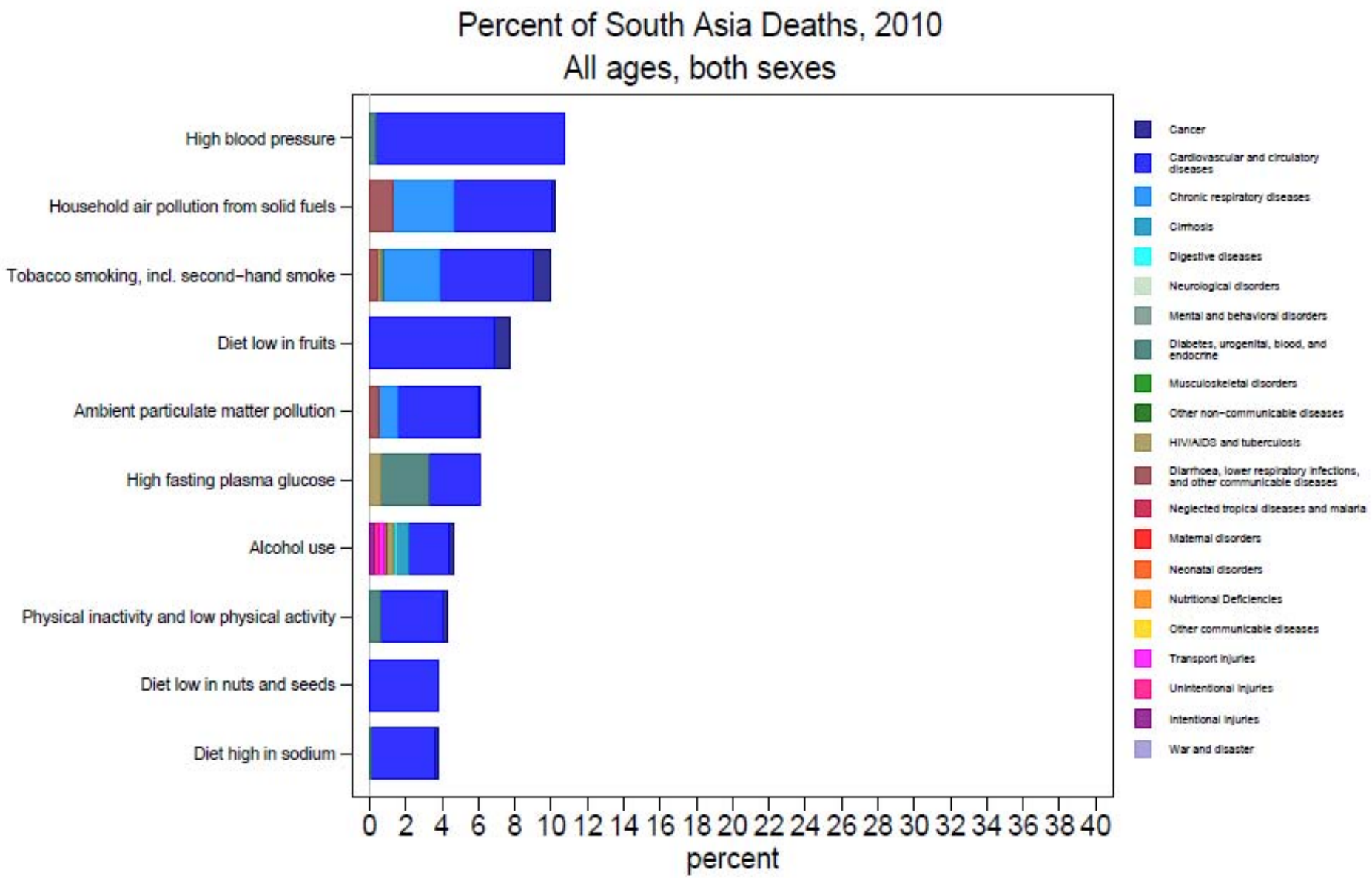
Secondhand cooksmoke

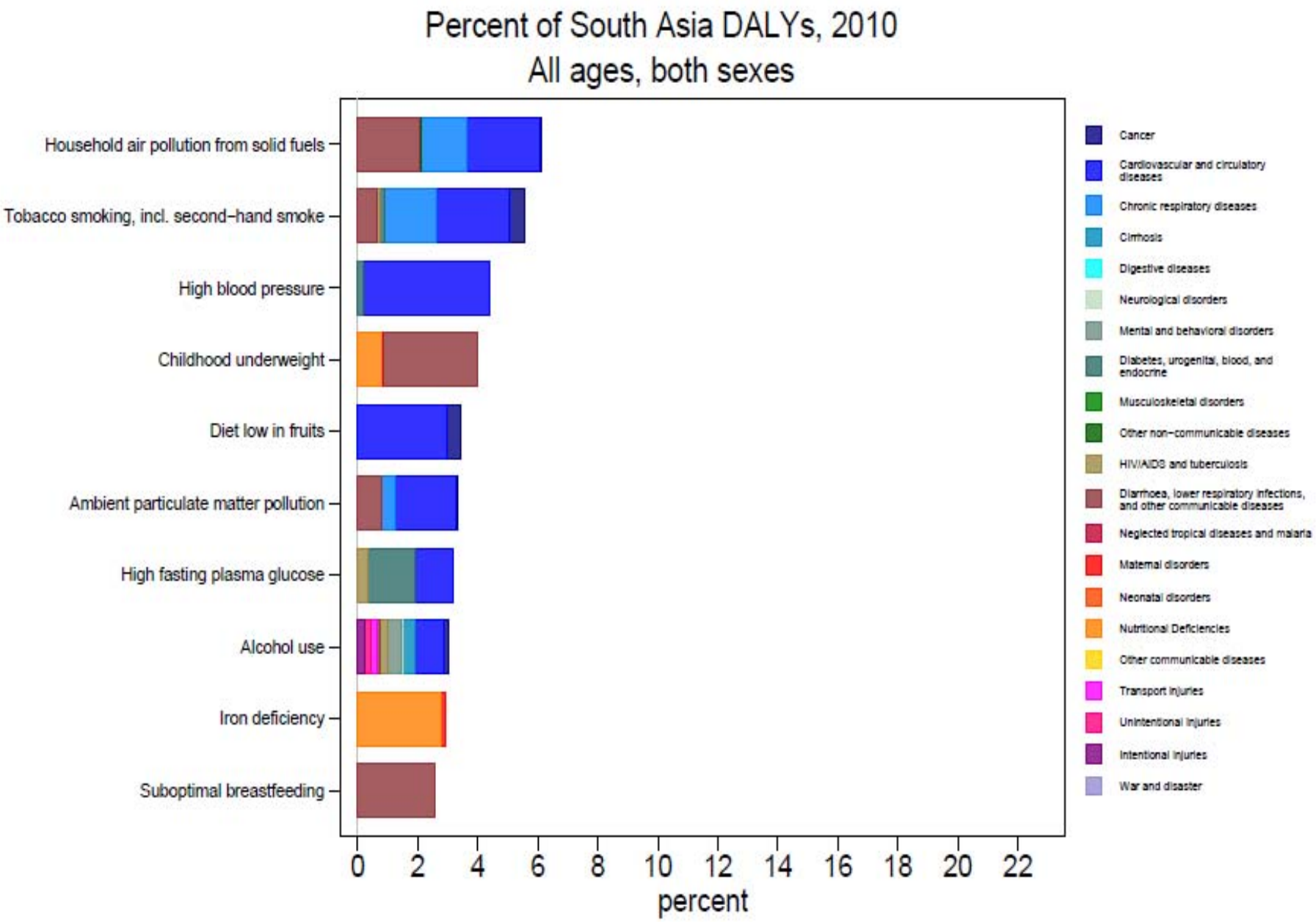
~150 thousand more

About 10% of national mortality

About the same as tobacco

In Nepal, this would be about 30,000


Percent of South Asia Deaths, 2010
All ages, both sexes
High blood pressure
Household air pollution from solid fuels
Tobacco smoking, incl. second-hand smoke
Diet low in fruits
Ambient particulate matter pollution
High fasting plasma glucose
Alcohol use
Physical inactivity and low physical activity
Diet low in nuts and seeds
Diet high in sodium
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
percent
Cancer
Cardiovascular and circulatory diseases
Chronic respiratory diseases
Cirrhosis
Digestive diseases
Neurological disorders
Mental and behavioral disorders
Diabetes, urogenital, blood, and endocrine
Musculoskeletal disorders
Other non-communicable diseases
HIV/AIDS and tuberculosis
Diarrhoea, lower respiratory infections, and other communicable diseases
Neglected tropical diseases and malaria
Maternal disorders
Neonatal disorders
Nutritional Deficiencies
Other communicable diseases
Transport injuries
Unintentional injuries
Intentional injuries
War and disaster


Percent of South Asia DALYs, 2010
All ages, both sexes
Household air pollution from solid fuels
Tobacco smoking, incl. second-hand smoke
High blood pressure
Childhood underweight
Diet low in fruits
Ambient particulate matter pollution
High fasting plasma glucose
Alcohol use
Iron deficiency
Suboptimal breastfeeding
0
2
4
6
8
10
12
14
16
18
20
22
percent
Cancer
Cardiovascular and circulatory diseases
Chronic respiratory diseases
Cirrhosis
Digestive diseases
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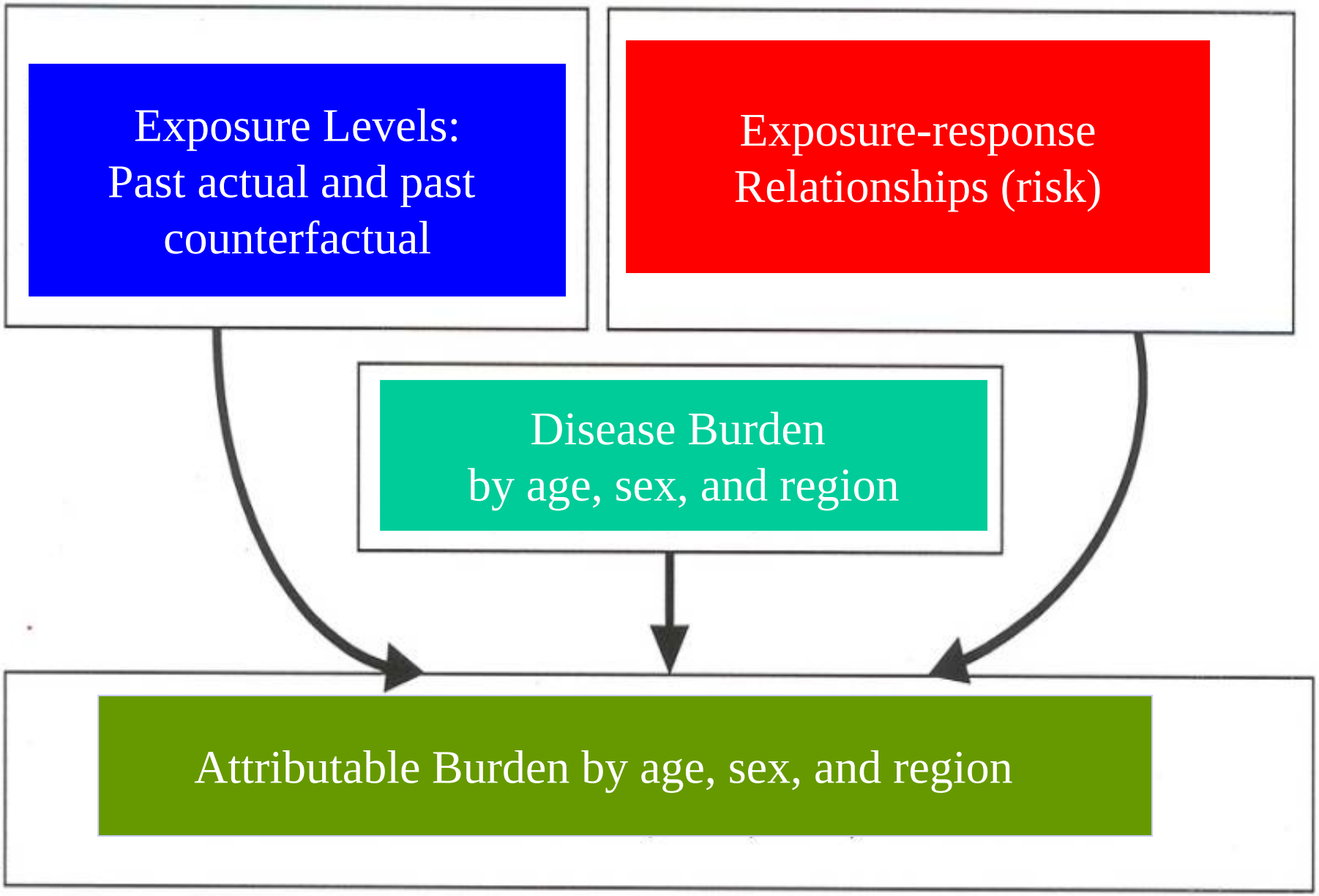
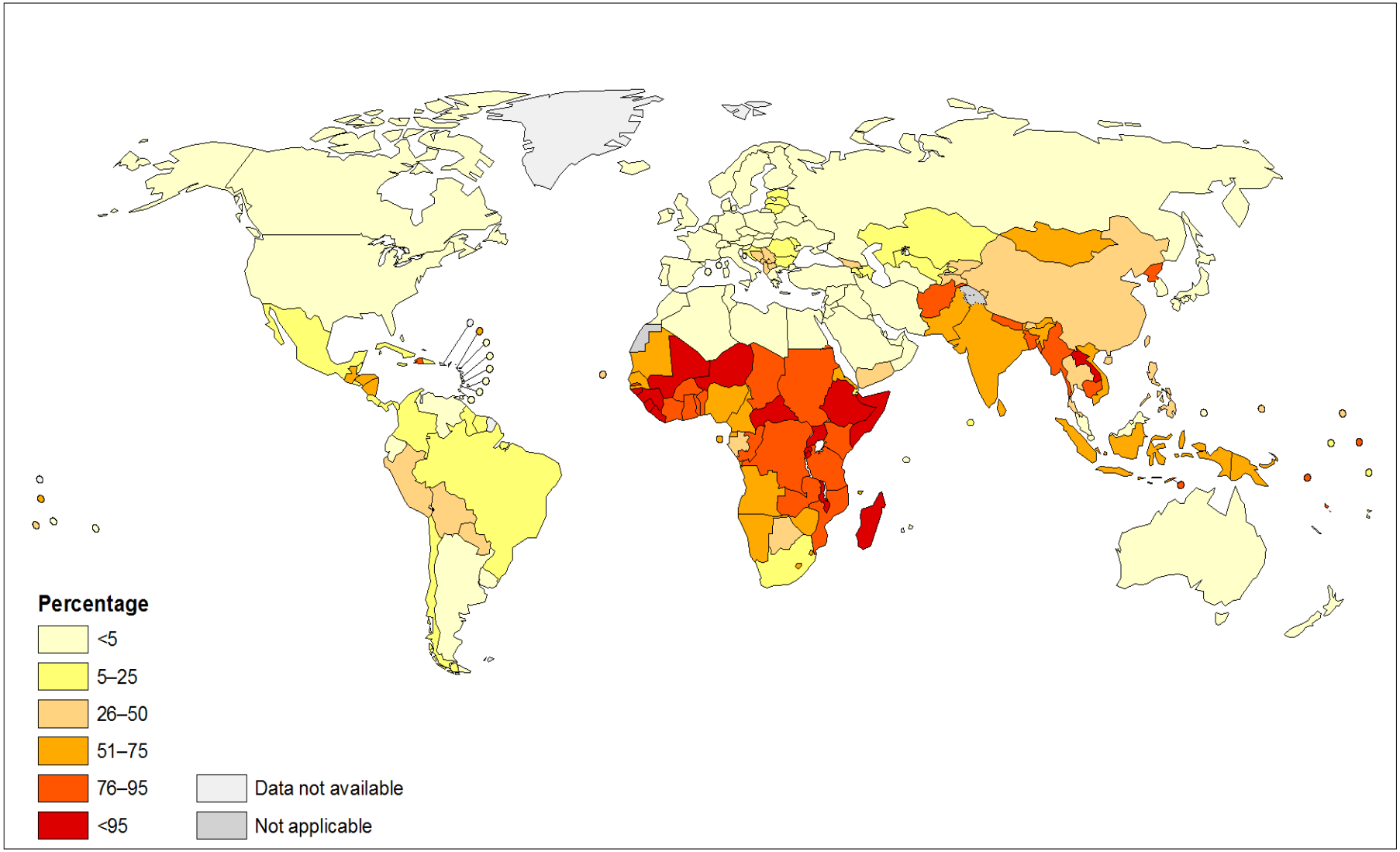
Comparative Risk Assessment Method



The framing

- Household air pollution from use of solid fuels for cooking
- Exposure based on percent of households using biomass or coal as their primary cooking fuel
- Country models informed now by ~600 nationally representative household surveys over 20+ years.
- Much less confusion with space heating, but not perfectly separated

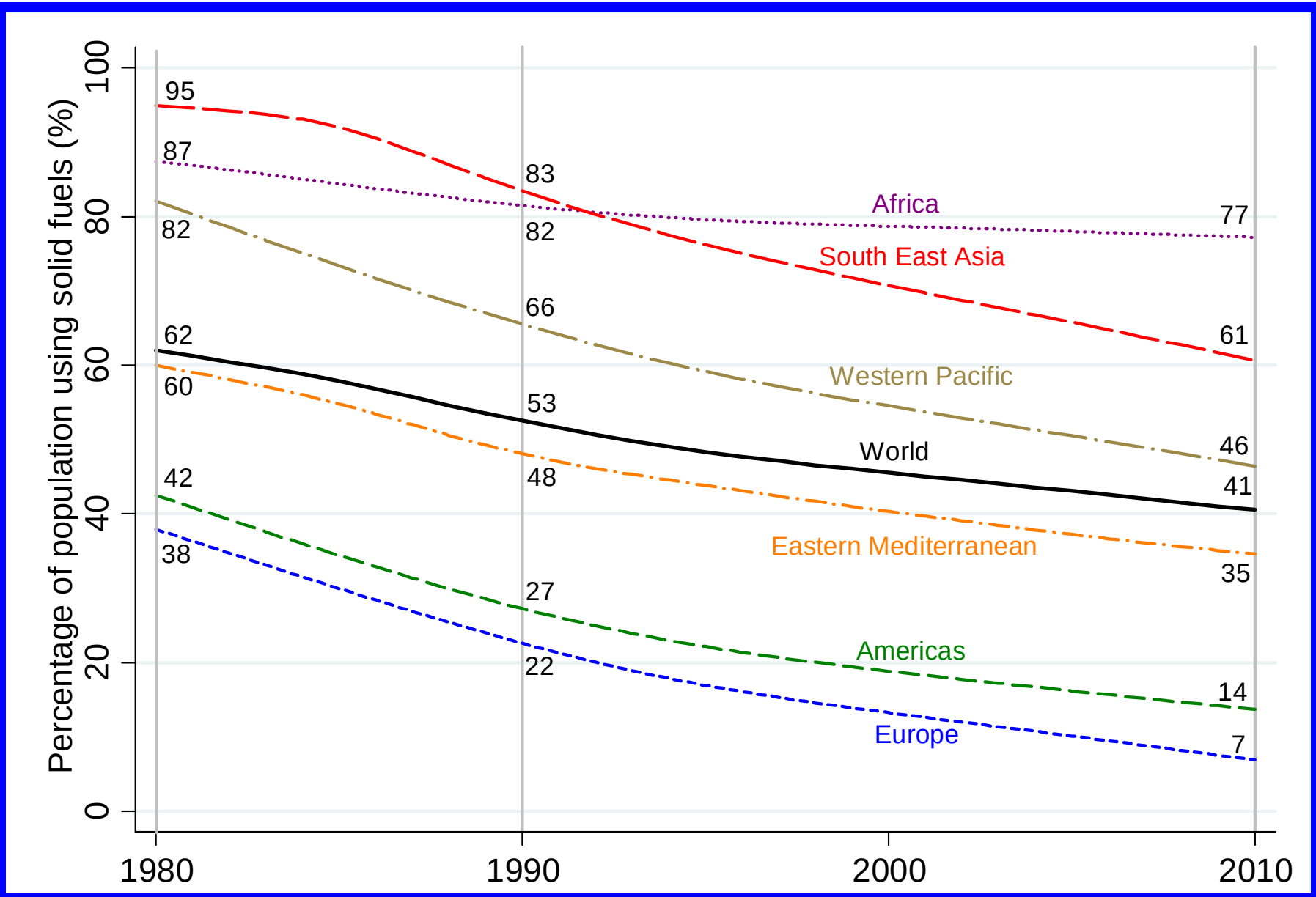
Population Cooking with Solid Fuels in 2010 (%)



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

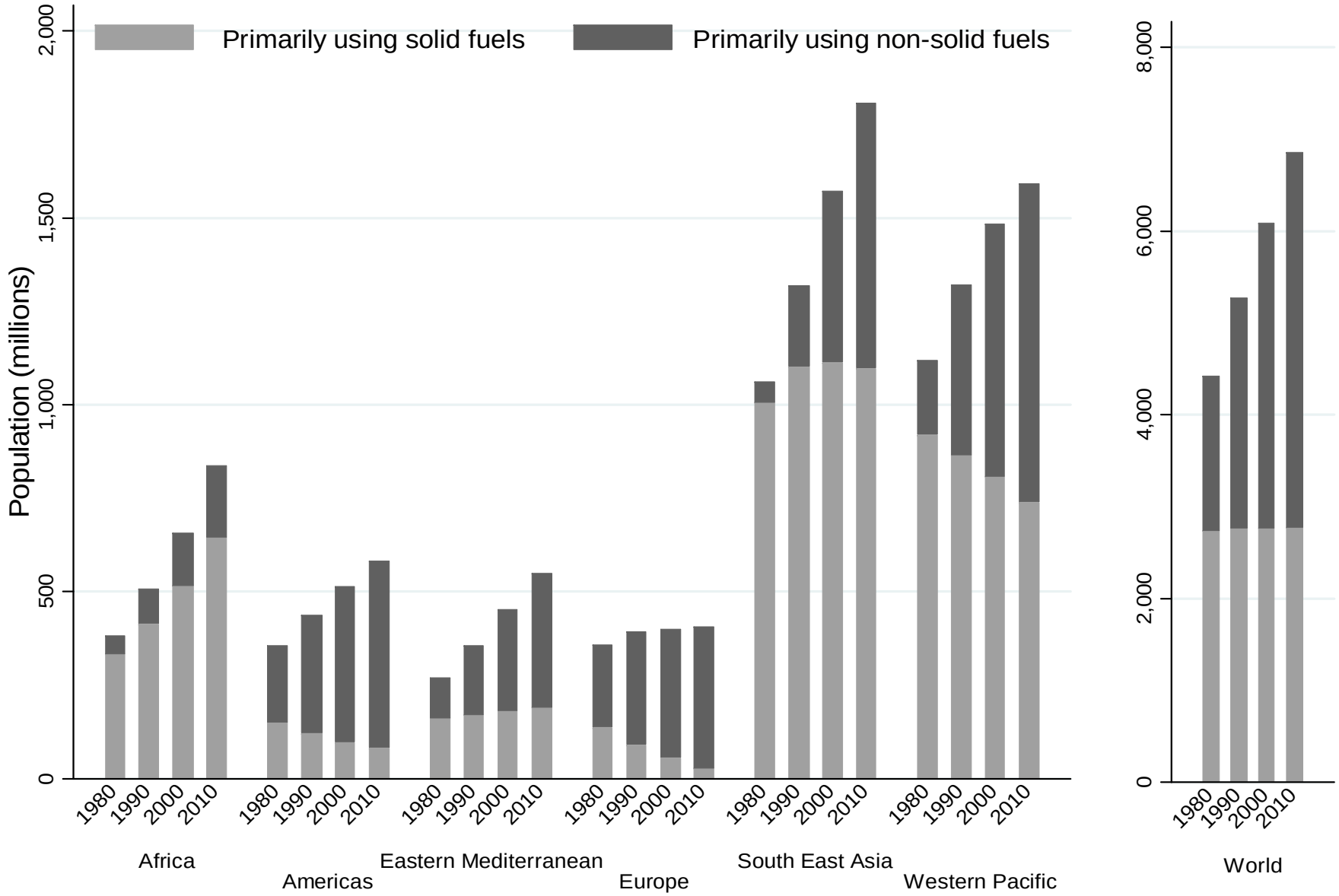
Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization



Percent of households cooking with solid fuels by region

Bonjour et al., GBD-2010



Total Population Cooking with Solid Fuels

Bonjour et al., CRA-2010

Nepal's Biomass Use for Cooking

- 2010: 82%
  - Bangladesh 91%
  - India 58%
  - Pakistan 64%
- Trends since 1980 in Nepal
  - Number of people increasing each year – shift to modern fuels occurring slower than population growth

Framing, cont

- Five major diseases now accepted to be caused by HAP
- Adults
  - Lung cancer
  - Chronic obstructive pulmonary disease
  - Cataracts
  - Cardiovascular disease - CVD
- Pneumonia in children

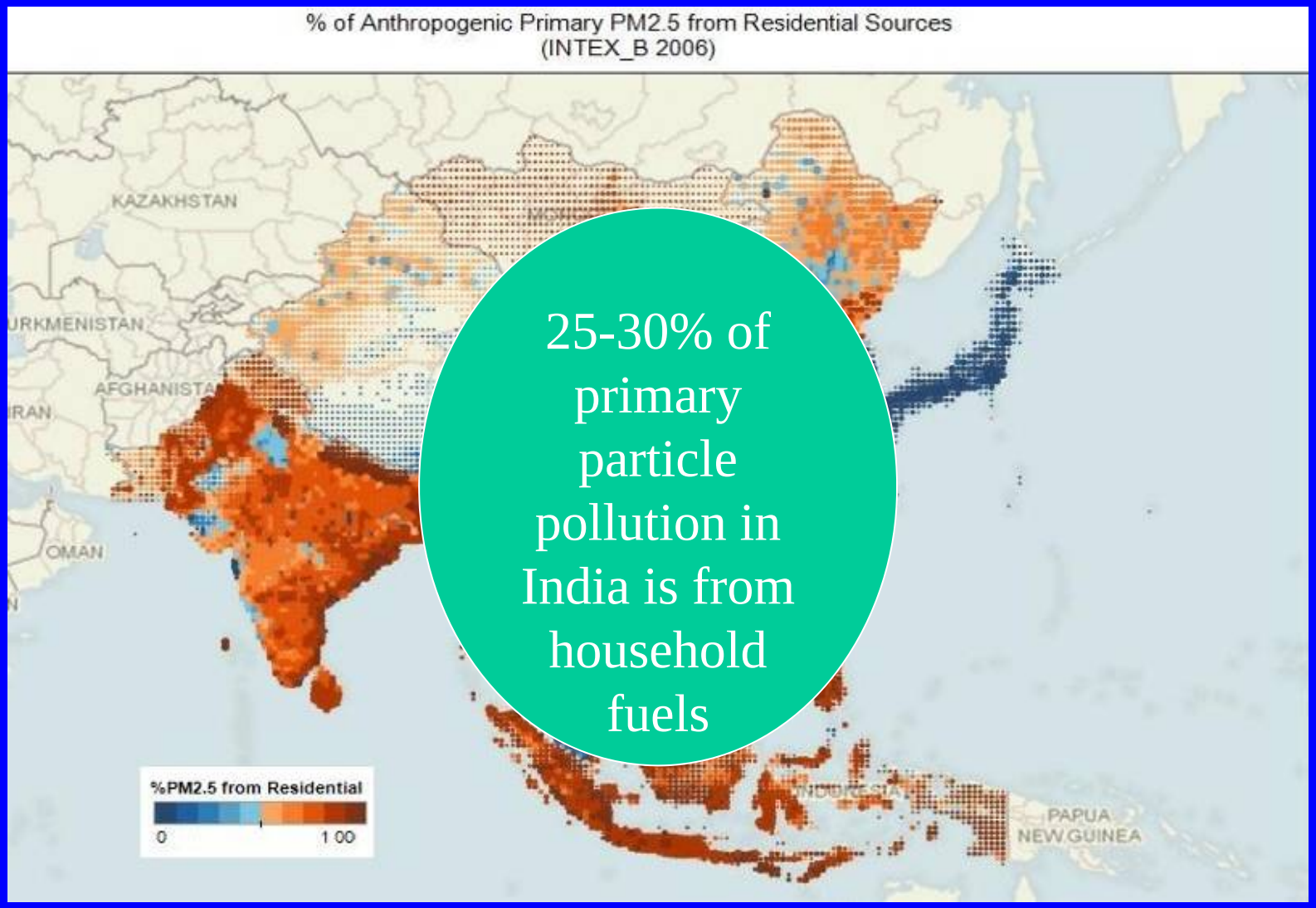
Framing, cont

- Two – COPD and cataracts -- use studies of health by fuel type for risk estimates
- CVD, lung cancer, and child pneumonia rely on risks determined by exposures derived from national model using 600+ household measurements in India & Bangladesh
- India itself not a small sample as it has more than one-quarter of the world total.
- Assumption is that rest of world, on average, similar.

Framing, cont.

- Not called “indoor” because stove smoke enters atmosphere to become part of general outdoor air pollution (OAP)
- HAP contributes about 16% to OAP globally, but much more in some countries
- Thus, part of the burden of disease due to OAP is attributable to cooking fuels in households ~500,000 premature deaths.

%$PM_{2.5}$ from "Residential" Emissions from INTEX_B



25-30% of primary particle pollution in India is from household fuels

Source: Asian Emission Inventory for NASA INTEX_B 2006 (accessed 2010)

Chafe, 2010

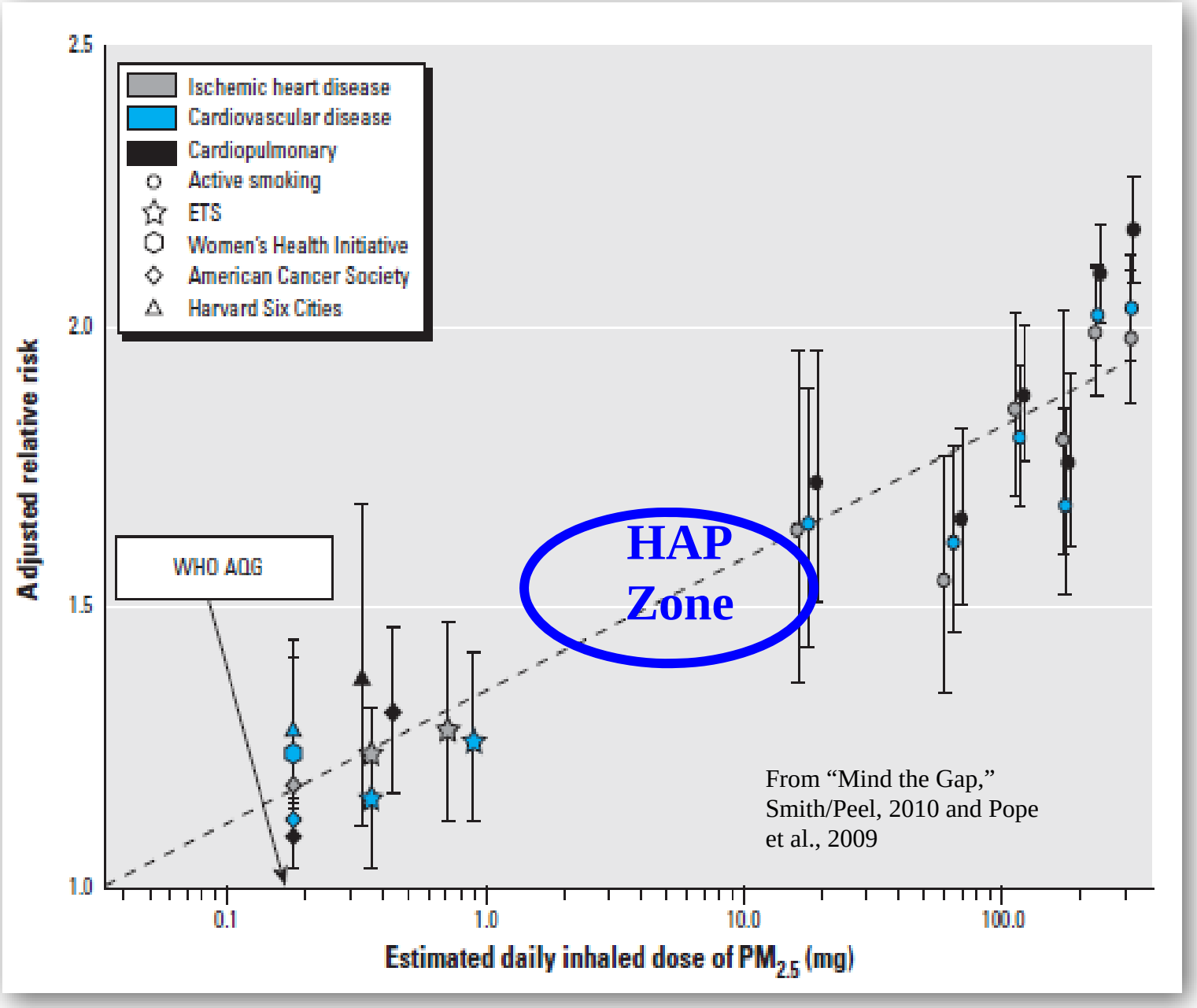
Framing, cont.

- Much effort made to make estimates consistent across the four combustion particle groups in the new GBD/CRA
- Active tobacco smoking, household air pollution, secondhand tobacco smoking, and outdoor air pollution
- HAP and OAP use the same counterfactual level for nearly all diseases: ~7 ug/m3 annual mean PM2.5 concentration
- Roughly equivalent to cooking with a vented gas stove or electricity

New Category of Evidence for CVD

- No direct studies of CVD and HAP, yet
  - But studies showing effects on blood pressure and ST-segment, important disease signs
- Epidemiologic evidence shows clear, consistent evidence of increasing risk across exposures to combustion particles
  - at higher exposures – Active smoking
  - and lower exposures – Outdoor air pollution and secondhand tobacco smoke

Heart Disease and Combustion Particle Doses



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

Chimney Stove Intervention to Reduce Long-term Wood Smoke Exposure Lowers Blood Pressure among Guatemalan Women

John P. McCracken,[1,2] Kirk R. Smith,[3] Anaité Díaz,[4] Murray A. Mittleman,[1,5] and Joel Schwartz[1,2]

EHP, 2007

Indoor Air Pollution and Blood Pressure in Adult Women Living in Rural China

Jill Baumgartner,[1,2,3] James J. Schauer,[3,4] Majid Ezzati,[5] Lin Lu,[6] Chun Cheng,[6] Jonathan A. Patz,[2,3,7] and Leonelo E. Bautista[2]

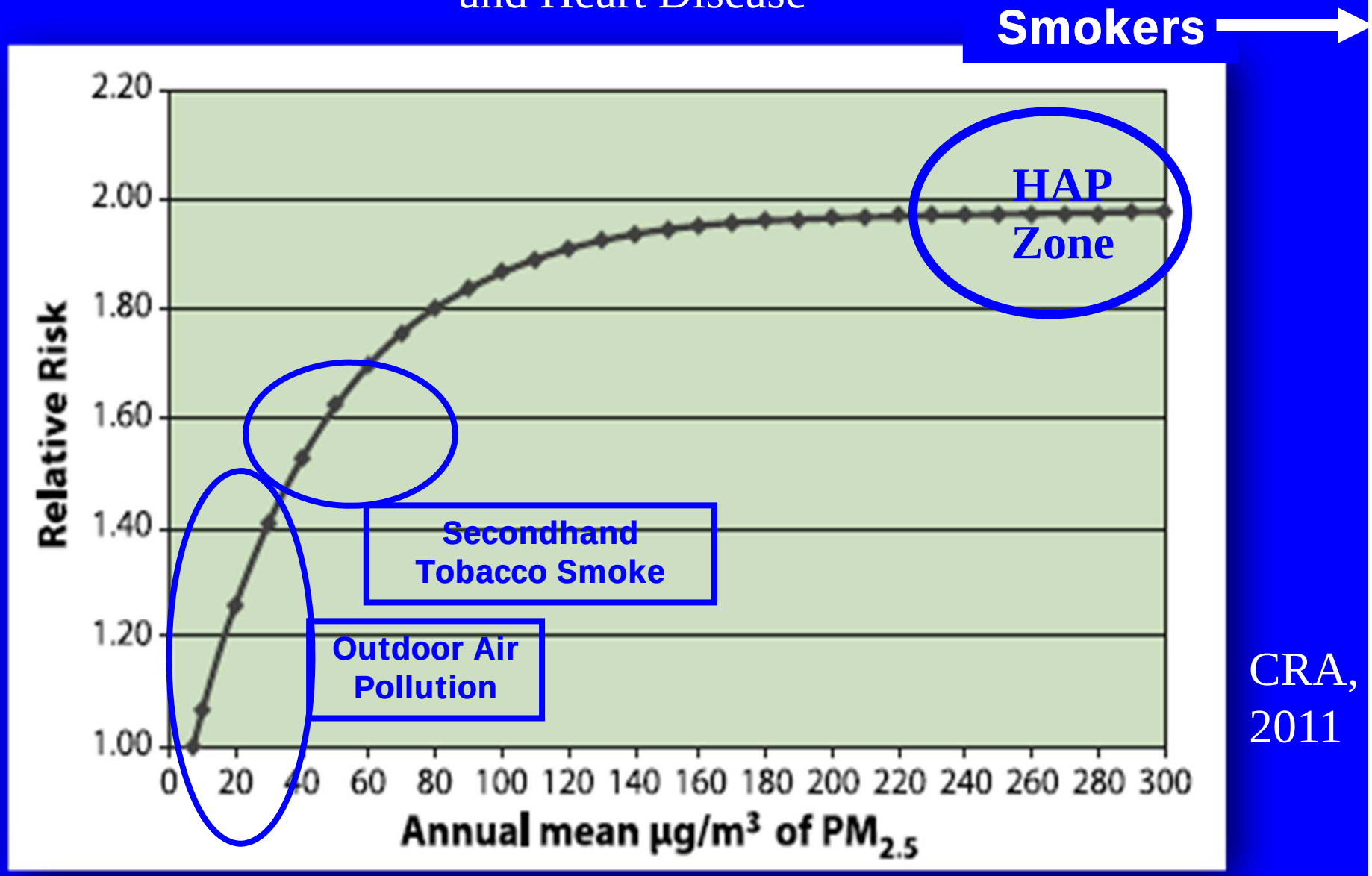
EHP, 2011

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]

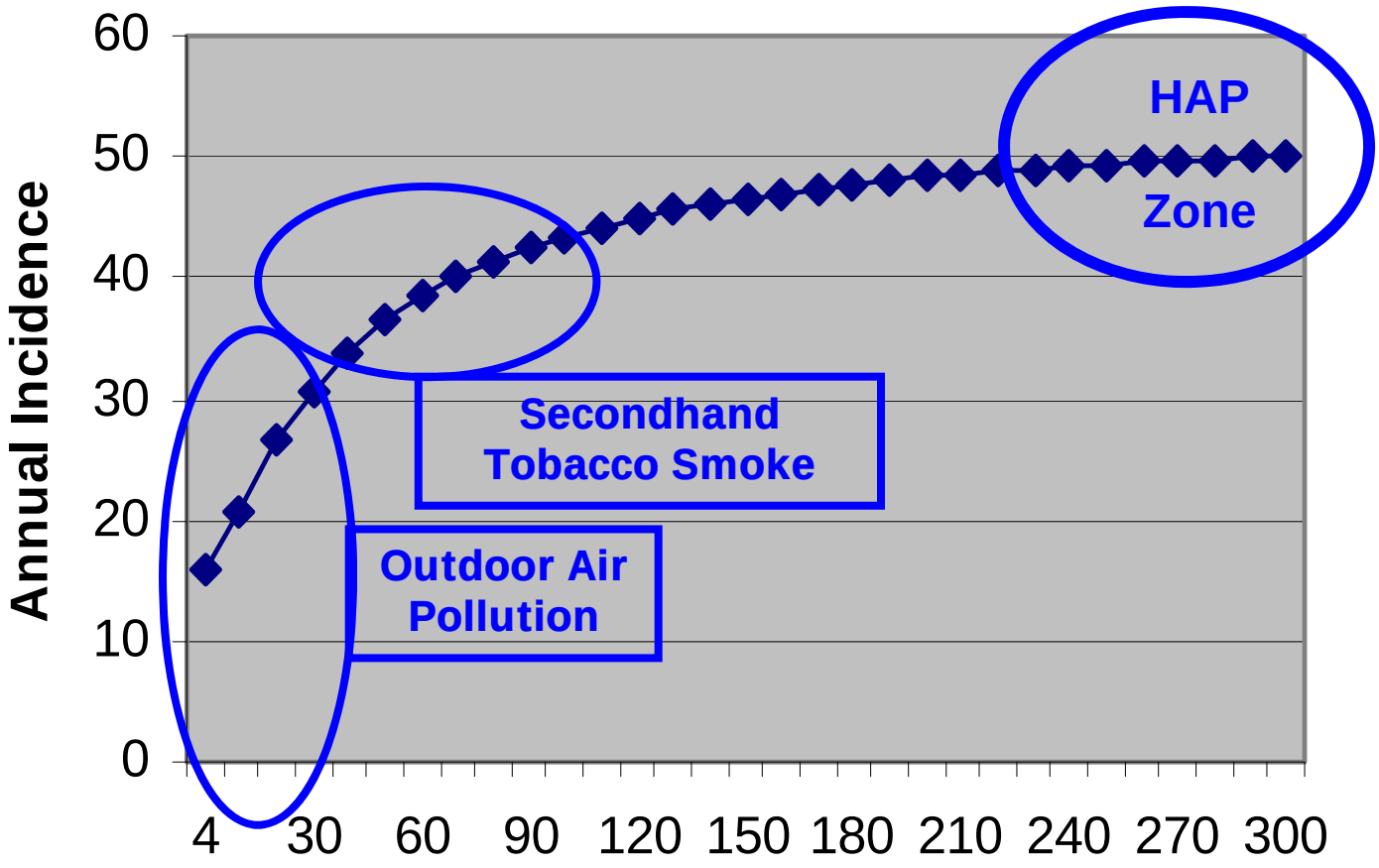
EHP, 2011

Integrated Exposure-Response: Outdoor Air, SHS, and Smoking and Heart Disease



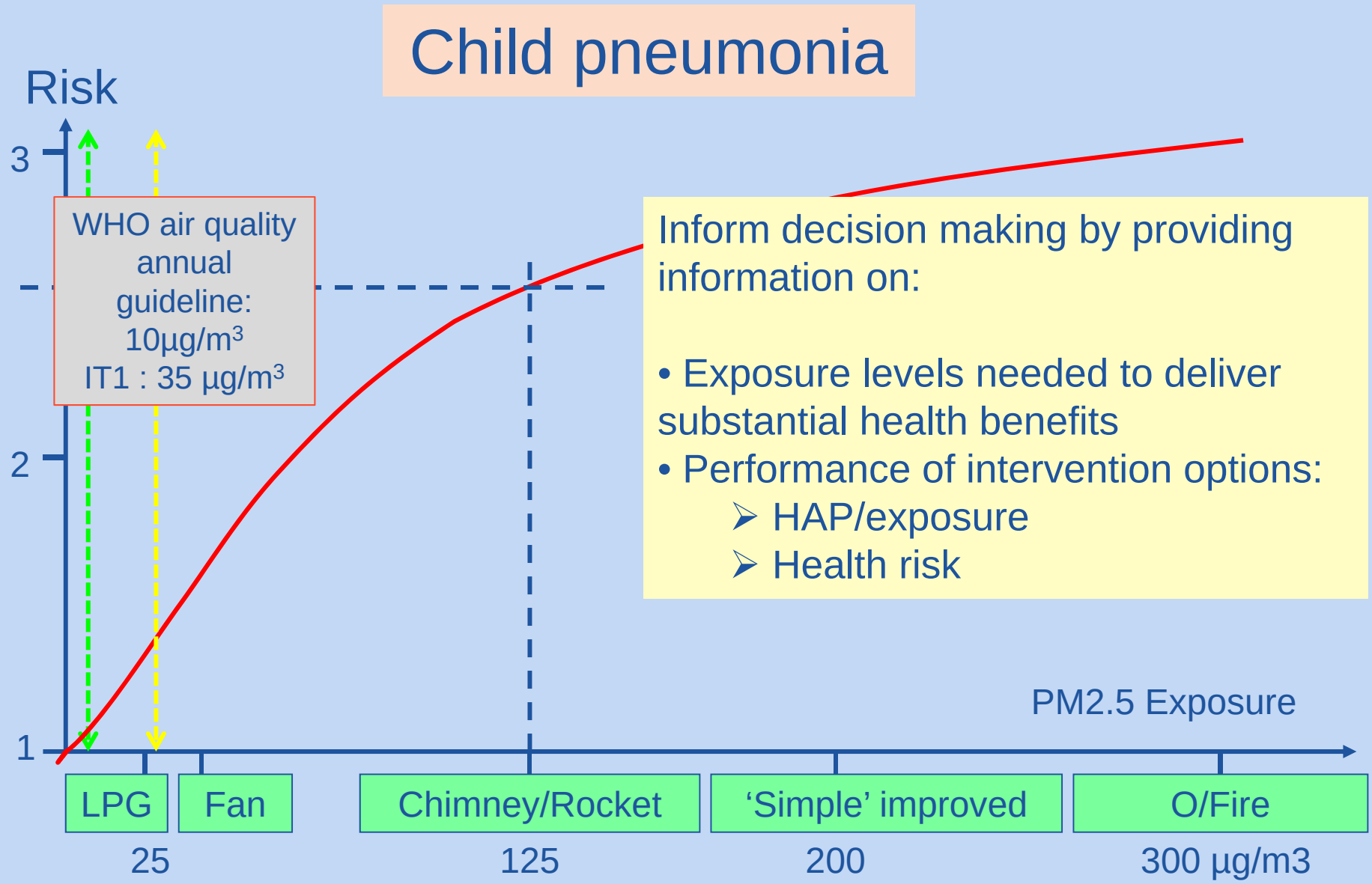
CRA, 2011

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



CRA, 2010

Exposure-response relationship



Inform decision making by providing information on:

- Exposure levels needed to deliver substantial health benefits
- Performance of intervention options:
  - HAP/exposure
  - Health risk

Bottom Lines

- One of the top risk factors in the world for ill-health.
- And in South Asia
- Most important environmental risk factor among all examined
- Biggest impact in adults --3 million premature deaths (two-thirds the DALYs)
- Still important for children ~500,000 deaths (one-third the DALYs)
- Important source of outdoor air pollution
- Impact going down slowly because background health conditions improving
- Actual number of people affected is not going down

Not all diseases included

- Many with evidence not included yet
  - Low birth weight
  - TB
  - Other cancers – cervical, upper respiratory, etc
  - Cognitive effects
  - Pneumonia in adults
- Can expect that HAP effects, over time, will be found for nearly all the many dozen diseases found for smoking.
- But at lower risk levels

Caveats

- Not all important risk factors were included in the GBD analysis, e.g.
  - None for malaria, HIV, child vaccinatable diseases, or road traffic accidents
- Portions of HAP CRA still under journal review – will likely be some changes
- Implied health benefit from HAP reduction only potentially achieved by shifting to clean cooking – gas & electricity

Bhaktapur Study of HAP and Child Pneumonia

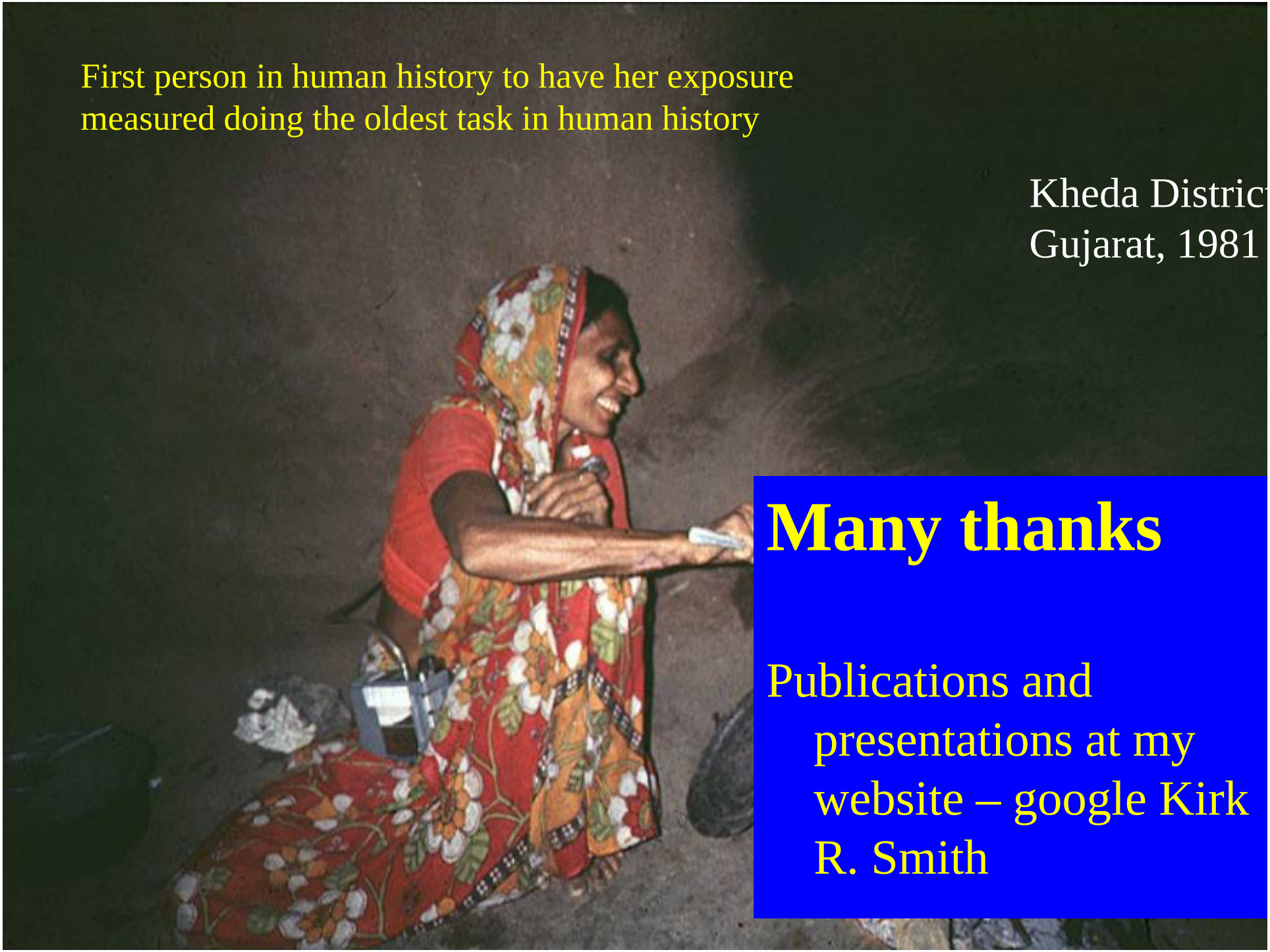
- 917 children (452 cases and 465 controls) were recruited into the study in 2006.
- Division of primary fuel use for cooking was almost equally divided among biomass, LPG, kerosene, and electricity.
- High-quality pneumonia (ALRI) surveillance conducted by associated randomized trial for zinc supplementation

Bhaktapur study, cont.

- Accepted for publication last Friday, Jan 11 in *Environmental Health Perspectives*
- Michael N Bates, Ram K Chandyo, Palle Valentiner-Branth, Amod K. Pokhrel, Maria Mathisen, Sudha Basnet, Prakash S Shrestha, Tor A Strand, Kirk R Smith.
- Berkeley, Norway, Denmark, and Child Health Department, Institute of Medicine, Tribhuvan University

Bhaktapur results

- Compared to use of electricity for cooking, use of biomass-burning primary stoves was associated with a 65% increase in ALRI
- Cooking with kerosene associated with a 73% increase
- Based on this, about 11% of the ALRI in the population is due to biomass cooking
- And 12% due to kerosene used for cooking.



Many thanks

Publications and presentations at my website – google Kirk R. Smith