Estimating the global health impacts from environmental risks

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Occupational and Environmental Health Seminar, University of Toronto - Dalla Lana School of Public Health, September 13 2024

DATA

DATA – context and perspective
    Success stories -> Hope

Identify priorities (and inequities)
    For policy action, regulation, research

Media and activism

Hans Rosling (GapMinder)

Our World in Data

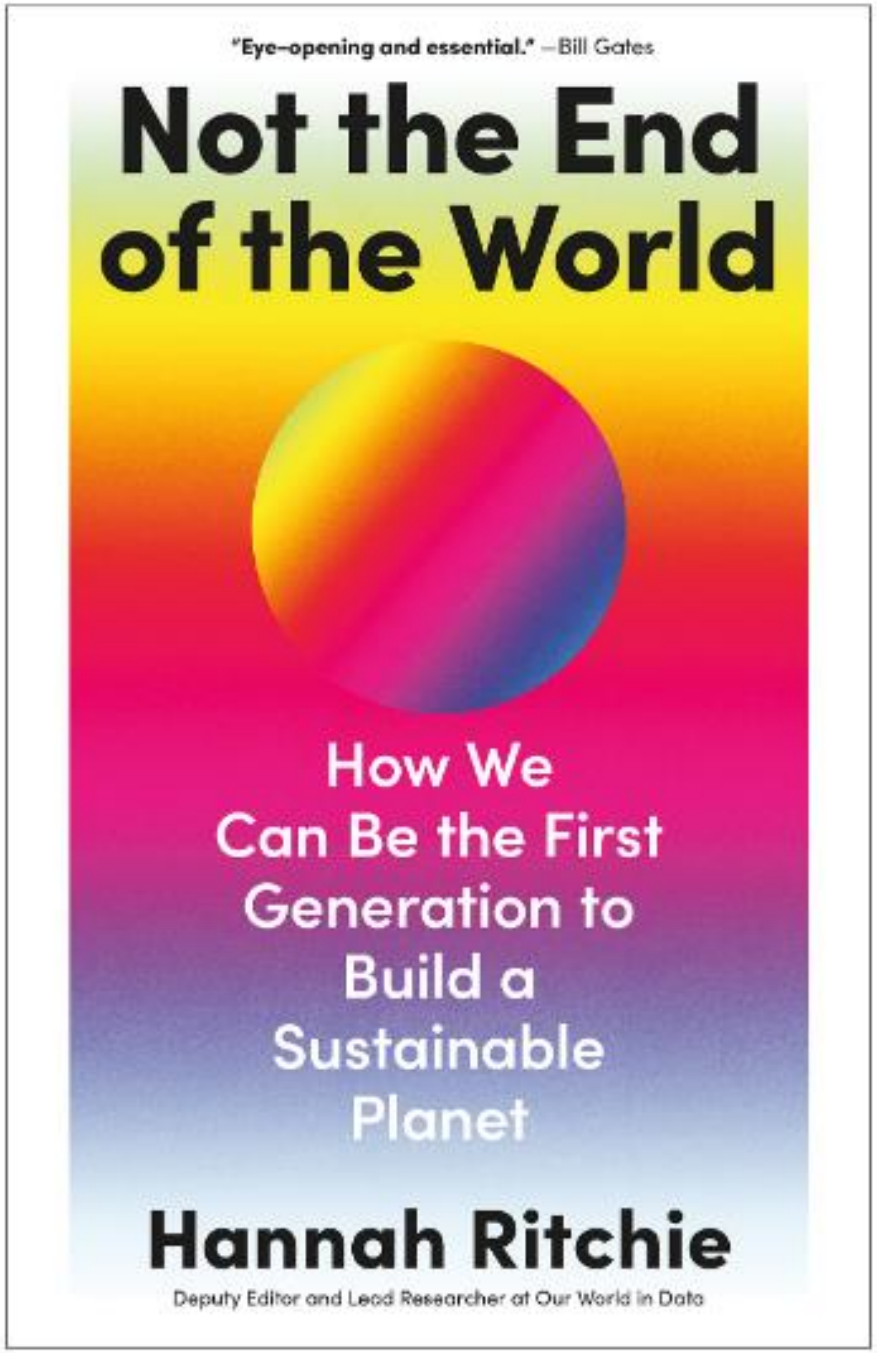
Yale Environmental Performance Index

Global Burden of Disease

CANUE

CAREX Canada

….



My story

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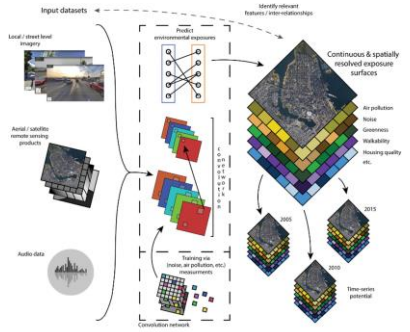
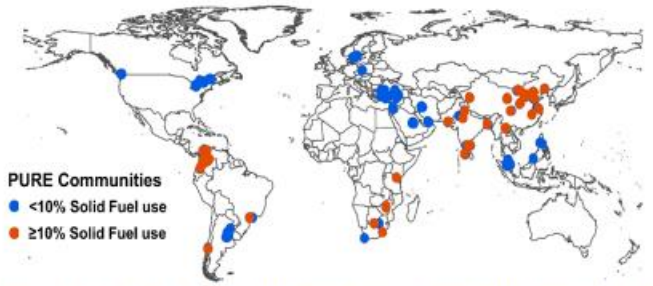
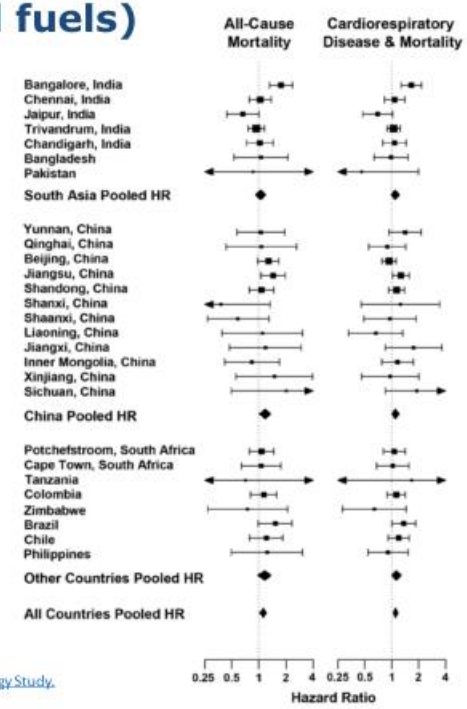


PURE

Household air pollution (Solid fuels)

	Events	Base	Adjusted
Mortality	6,595	1.24 (1.15-1.33)	1.12 (1.04-1.21)
CVD Events	5,472	1.06 (0.98-1.14)	1.08 (0.99-1.17)
Resp. Events	2,436	1.29 (1.14-1.46)	1.14 (1.00-1.30)

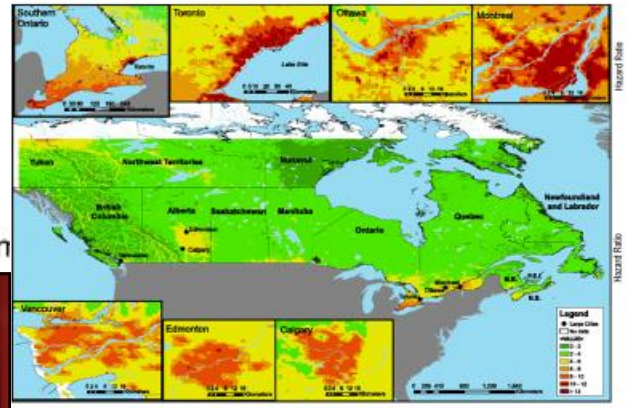


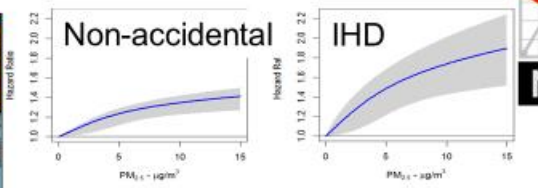


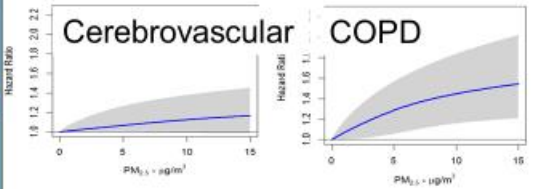
Health Effects of Household Solid Fuel Use: Findings from 11 Countries within the Prospective Urban and Rural Epidemiology Study.
Hystad et al. Environ Health Perspect. 2019 May;127(5):57003. doi: 10.1289/EHP3915.

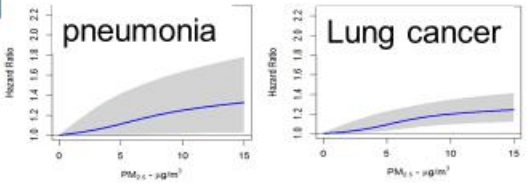
2001 Canadian Census Health and Environment Cohort

MAPLE









- 1 km satellite-based estimates
- 2.4 million non-immigrant adults 25-90
- 10 year follow-up

- ~500,000 adults (CCHS)
- 5 – 15 year follow-up, extensive covariates adjustment

Pinault et al., Environ Health. 2016 Feb 11:15:18:Pinault et al., Environ Res. 2017 Nov;159:406-415


OKI


FOR USE AS A
MOTOR FUEL ONLY
CONTAINS
LEAD

Why assess disease burden?

- Prioritization
  - Current status
  - Geographical variation
- Trends
  - assess effectiveness if interventions / identify new challenges
- Identification/ranking of **modifiable risk factors**
- Methodology / understanding of disease processes and risk factors

Common questions

- What is the total impact of disease and injury in the population? -- the overall target for public health interventions? (Disease Burden)
  - 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? (Attributable Burden)
  - What is the burden of disease from environmental factors?
  - How does the impact of tobacco smoking compare to that from air pollution?

Global Burden of Disease: Measuring What Matters

- A ***systematic, scientific*** effort to quantify the ***comparative*** magnitude of ***health loss*** due to diseases, injuries, and risk factors by age, sex, and geographies for specific points in time.

  - Broad Vision:
    - Everyone deserves to live a long life in full health.
  - Essential Goal:
    - Identify what is preventing populations from living longer and healthier lives.
  - Justification:
    - You can't save lives if you don't know what people are dying from.
    - You can't make people healthier if you don't know what is making them sick.

WHO definition

"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, World Health Organization Constitution (1946)
http://www.ldb.org/iphw/whoconst.htm

"spiritual well-being" added in 1999

"The extent to which an individual or group is able, on the one hand, to realize aspirations and satisfy needs; and, on the other hand, to change or cope with the environment"

- Alma Ata Declaration, international conference on primary health care (WHO, 1978)

Eight Principles

1. **Comprehensive** comparisons, aka leave no blanks
2. Communicate the **strength** of the evidence
3. Ensure internal **consistency**
4. **Iterative** approach to estimation
5. Identify **all relevant data** sources
6. Compare like with like, aka crosswalk different measurements
7. **Correct** for data errors
8. Pick the best model based on **performance**

Aim:

Make estimates:

(i) comprehensive,
(ii) comparable, &
(iii) as accurate as possible.

Focusing on *all* aspects of health loss

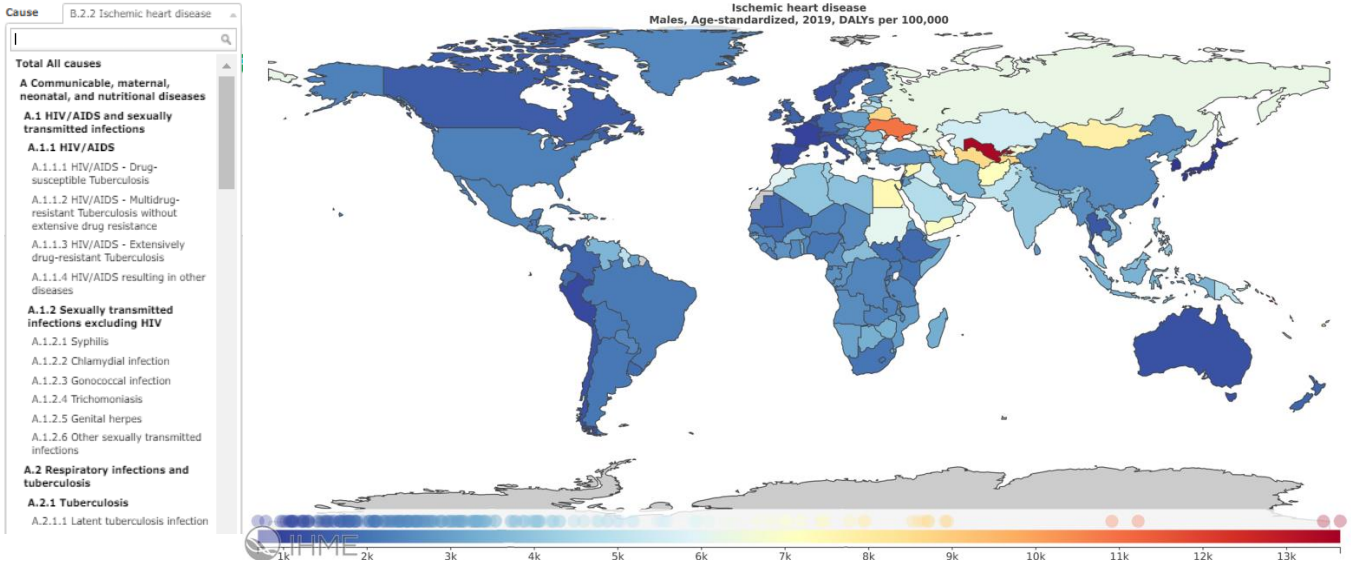
GBD aims to produce **comprehensive and comparable** estimates of ***all*** **forms of health loss** (diseases, injuries, impairments) for **every country** in the world.

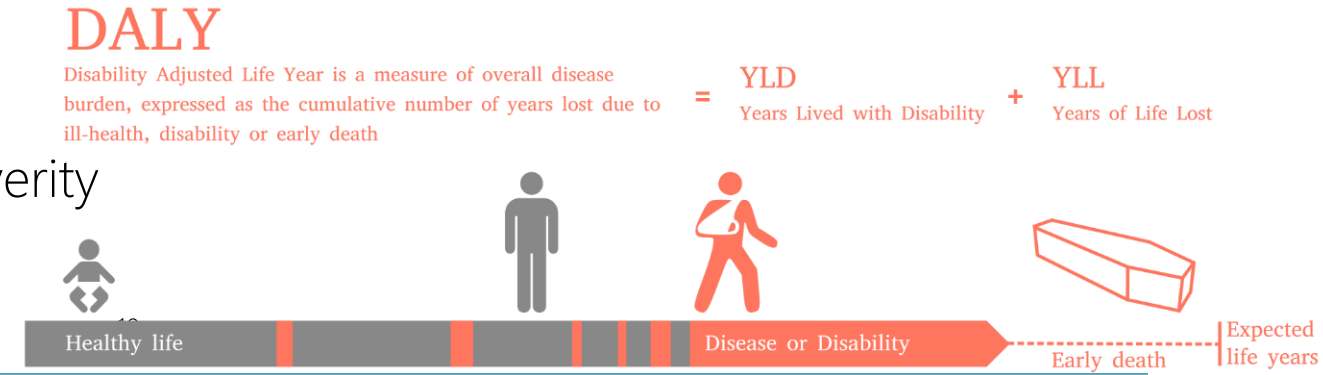
Traditional Metrics:

- Death counts, mortality rates
- Incidence, prevalence

Novel Metrics:

- Years of life lost (**YLL**s) to premature death
- Years lived with disability (**YLD**s)
  - Time spent sick or injured
    - With disability weight accounting for severity
- Disability adjusted life years (**DALY**s)



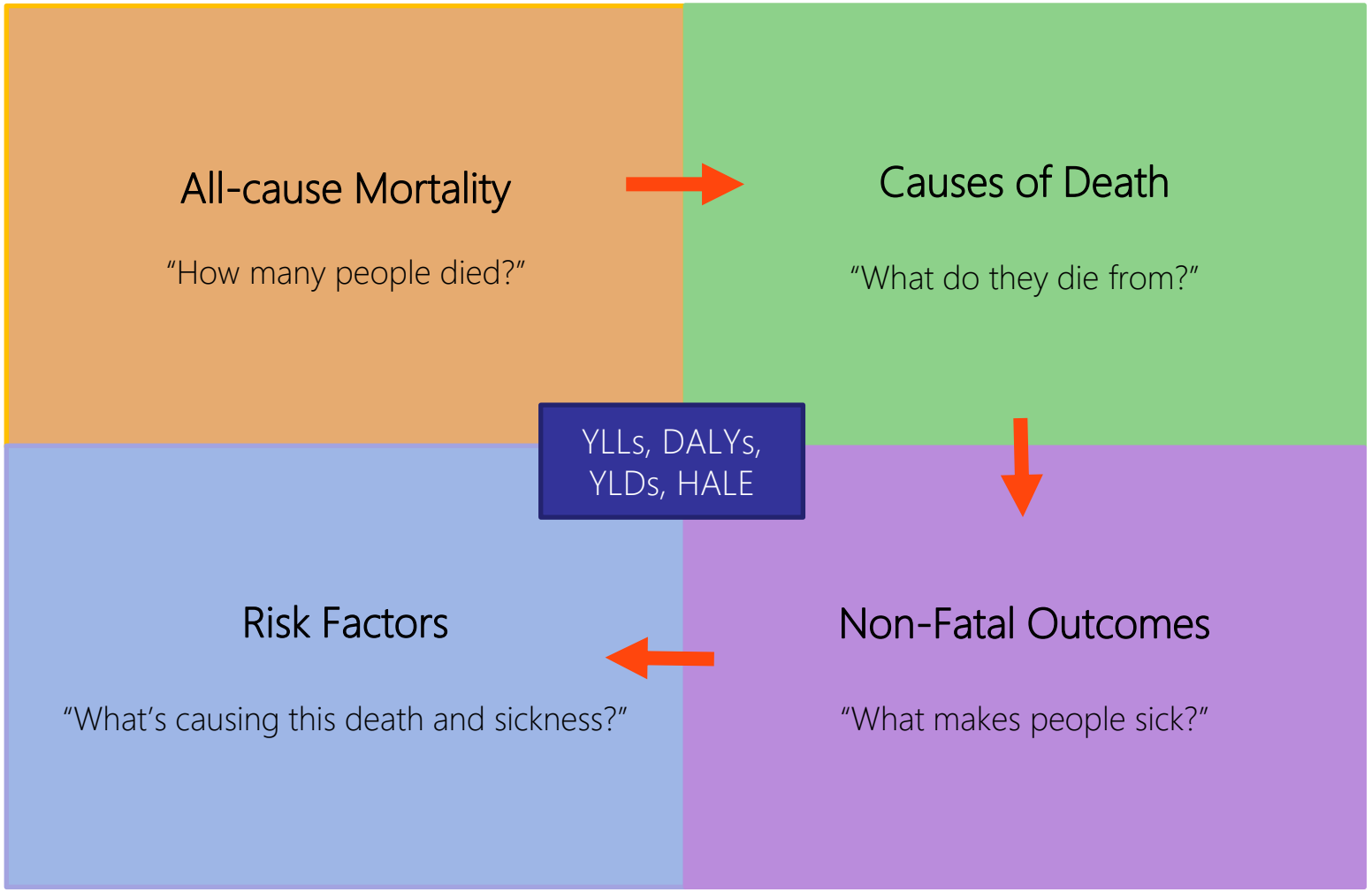


Measures of health: Burden of Disease

- Mortality = Numbers of Deaths
- Burden = Disability Adjusted Life Year (DALY)
  - 1 DALY = 1 lost year of **healthy** life

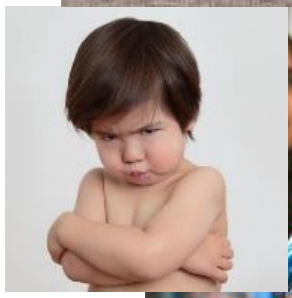
- DALY = YLL + YLD
  - *years of life lost because of premature death (YLLs)*
  - *years of life lived with disability (YLDs)*

Four “Building Blocks” of GBD Estimation



Dimensions of the GBD

- **Geographic:** 1075 modeling locations
  - 204 countries and 811 sub-national locations
    - Subnational analyses: Brazil, China, England, Ethiopia, India, Indonesia, Iran, Japan, Kenya, Mexico, Norway, Pakistan, Russia, South Africa, Sweden, USA,
- **Ages:** 5-year age bands (1-4, 5-9, 10-14….95+)
  - <5 years: 06d, 7-27d, 28-364 d, 1-4 years
  - 10 aggregate groups: <5, 5-14 years, 10-24 years, <20 years, 15-49 years, 50-69, 70+, 80+, All ages, age-standardized
- **Sex:** Male, Female, both sexes combined
- **Causes:** 369 distinct causes
- **Risk factors:** 88 risk factors



"for every population" = every age/sex/location/year combination

Diseases and injuries in the GBD datasets form a hierarchy of 369 causes, mutually exclusive and exhaustive, of all-cause mortality

Group I: Communicable, maternal, neonatal, nutritional diseases
- HIV/AIDS and tuberculosis
- Diarrhea, lower respiratory, other common infectious diseases
- Neglected tropical diseases and malaria
- Maternal disorders
- Neonatal disorders
- Nutritional deficiencies
- Other communicable, maternal, neonatal, nutritional diseases

Group II: Non-communicable diseases
- Neoplasms (cancers)
- Cardiovascular diseases
- Chronic respiratory diseases
- Cirrhosis and other chronic liver diseases
- Digestive diseases
- Neurological disorders
- Mental and substance use disorders
- Diabetes, urogenital, blood, endocrine diseases
- Musculoskeletal disorders
- Other non-communicable diseases

Group III: Injuries
- Transport injuries
- Unintentional injuries
- Self-harm and interpersonal violence
- Forces of nature, war, legal intervention

Higher-level group data can be interrogated in progressively greater detail:

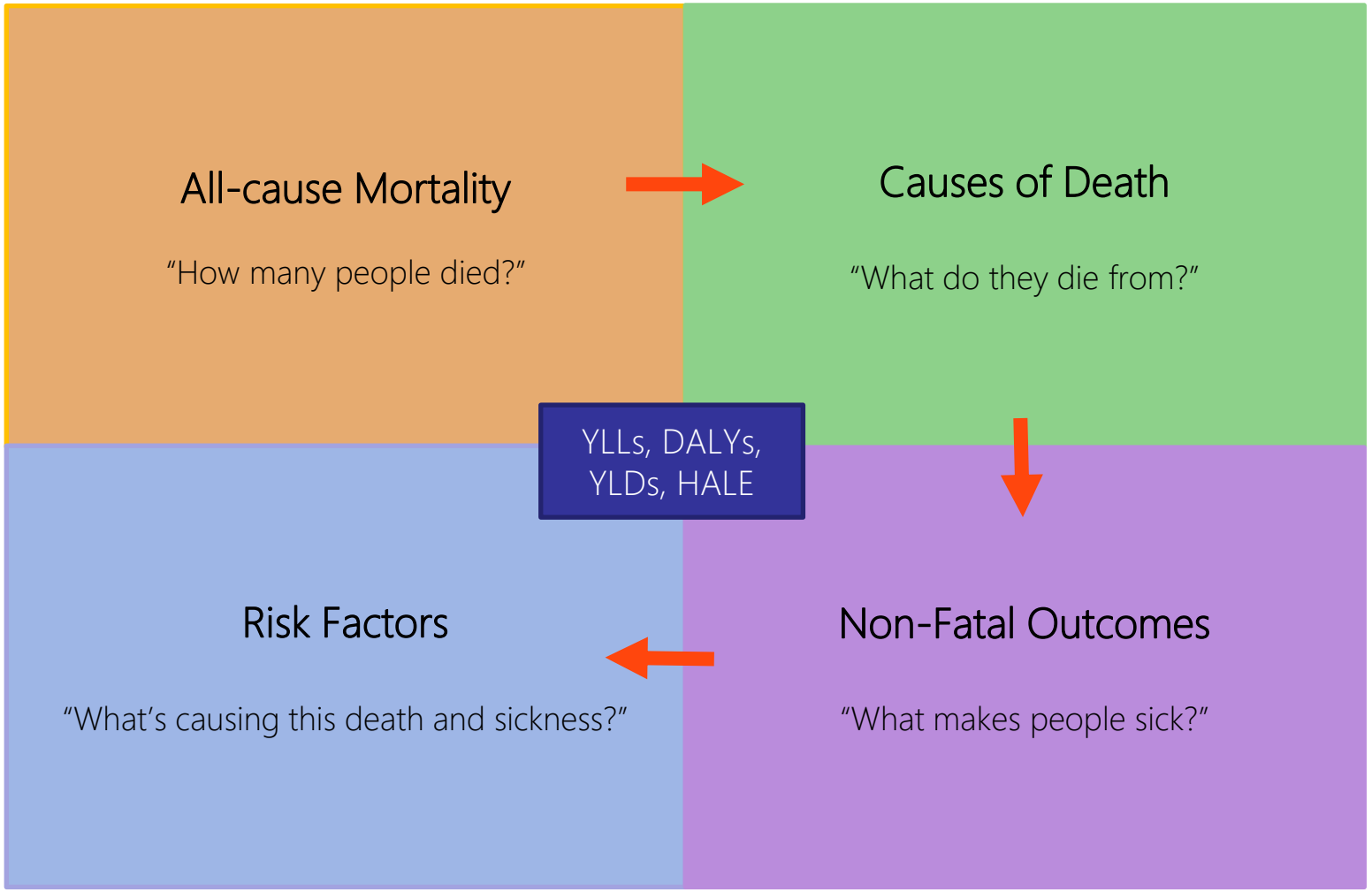
Neoplasms (cancers)
- Esophageal cancer
- Stomach cancer
- Colon and rectum cancer
- Liver cancer
- Gallbladder and biliary tract cancer
- Pancreatic cancer
- Larynx cancer
- Tracheal, bronchus, lung cancer
- Malignant skin melanoma
- Non-melanoma skin cancer
- Breast cancer
- …

Liver cancers
- Liver cancer due to hepatitis B
- Liver cancer due to hepatitis C
- Liver cancer due to alcohol use
- Liver cancer due to other causes

Mental and substance use disorders
- Schizophrenia
- Alcohol use disorders
- Drug use disorders
- Depressive disorders
- Bipolar disorder
- Anxiety disorder
- Eating disorders
- Autistic spectrum disorders
- Attention-deficit/hyperactivity disorder
- Conduct disorder
- …

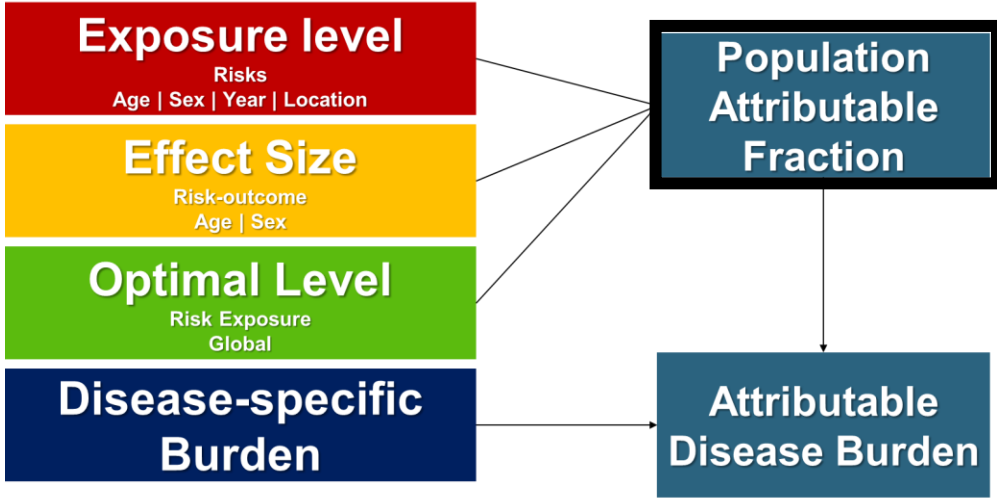
Drug use disorders
- Opioid use disorders
- Cocaine use disorders
- Amphetamine use disorders
- Cannabis use disorders
- Other drug use disorders

Four “Building Blocks” of GBD Estimation



Risk factor attributable burden

$$PAF_{joasct} = \frac{\int_{x=l}^{u} RR_{joas}(x)P_{jasct}(x)dx - RR_{joas}(TMREL_{jas})}{\int_{x=l}^{u} RR_{joas}(x)P_{jasct}(x)dx}$$



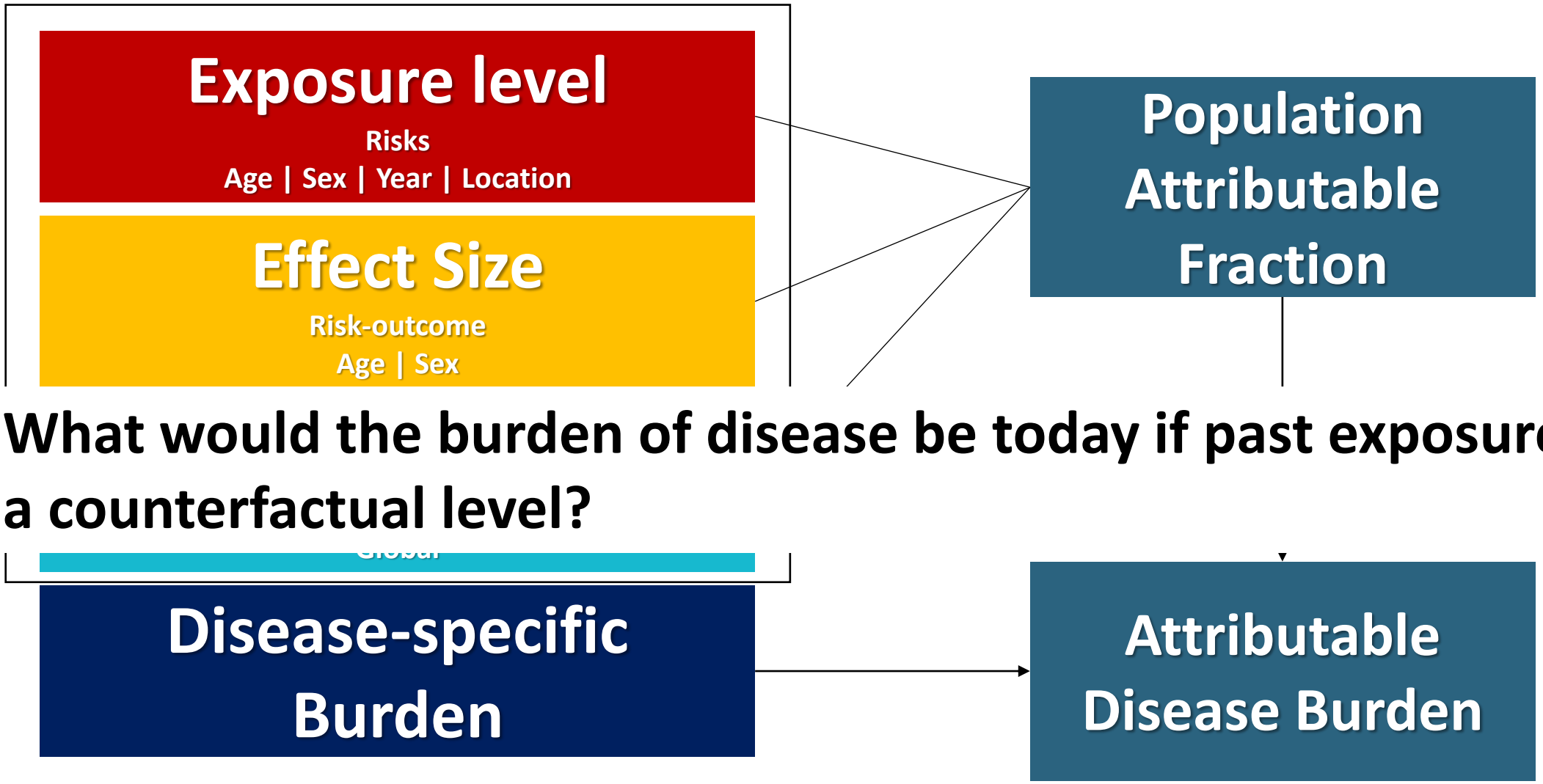
Population attributable fraction: excess outcomes (deaths, DALYs etc) attributable to risk factor minus the rates seen in the lowest risk category divided by the total events in the population

RR is relative risk
P is exposure prevalence at different levels of risk *x*.
TMREL is the theoretical minimum risk exposure level

Attributable Burden

- **Attributable fraction** X Deaths (cause-specific)
- **Attributable fraction** X DALYs (cause specific)

Risk factor attributable burden

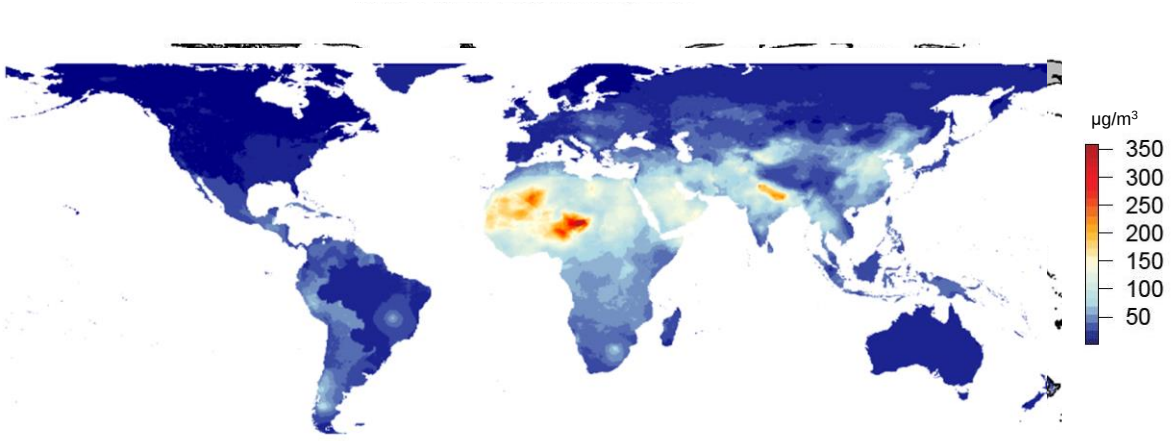


What would the burden of disease be today if past exposure was set to a counterfactual level?

Combining satellite and ground monitoring to estimate exposure

$$\log(PM_{2.5st}) = \beta_{0st} + \beta_{1st}\log(SAT_s) + \beta_{3..P}X_{st} + \varepsilon_{st}$$

Bayesian Hierarchical Model (DIMAQ2)



Spatially varying determinants of AOD-$PM_{2.5}$ relationship (from chemical transport model, other) + hierarchical random effects

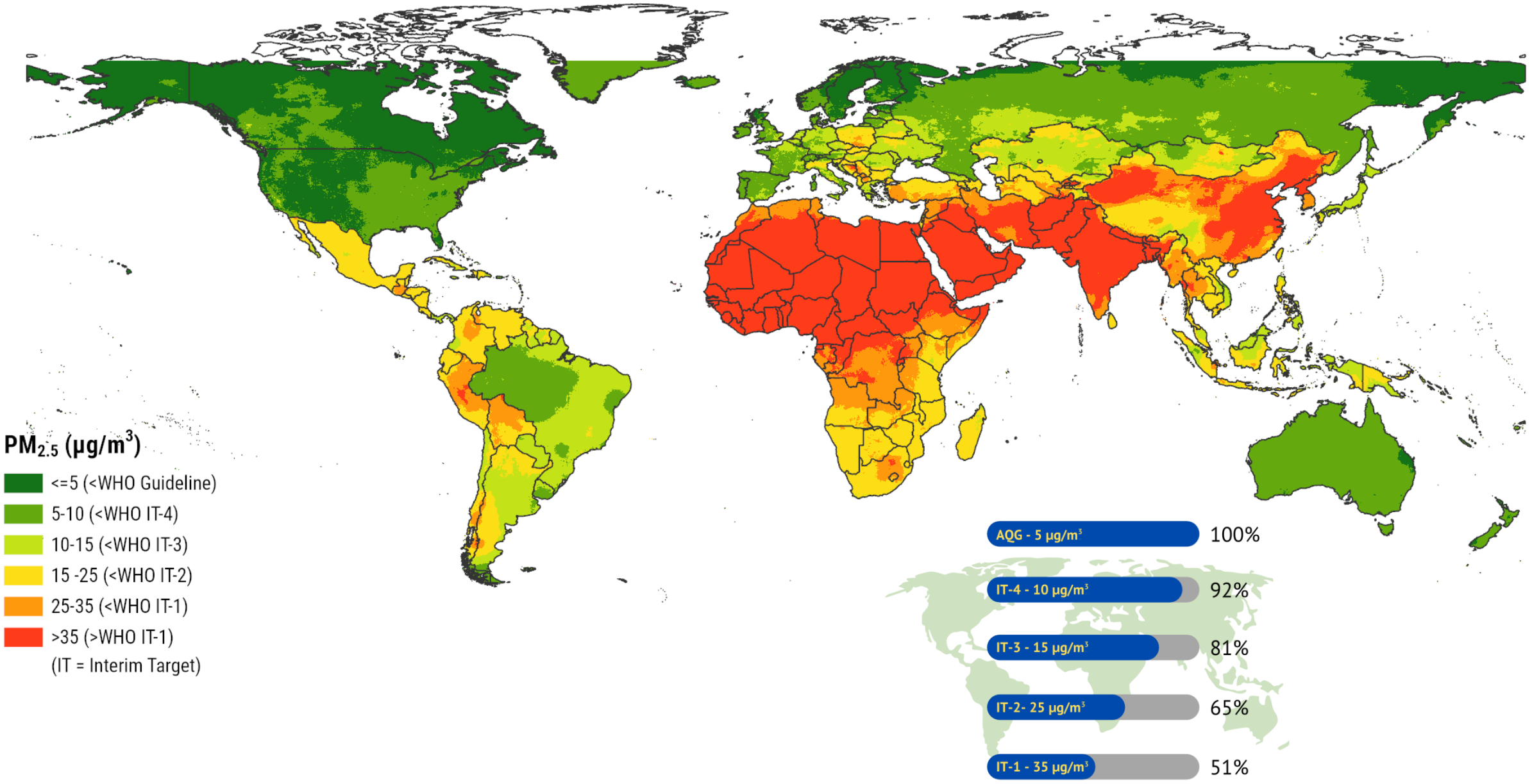
Ground measurements, GBD 2021
N = 18,406 unique locations, from 120 countries

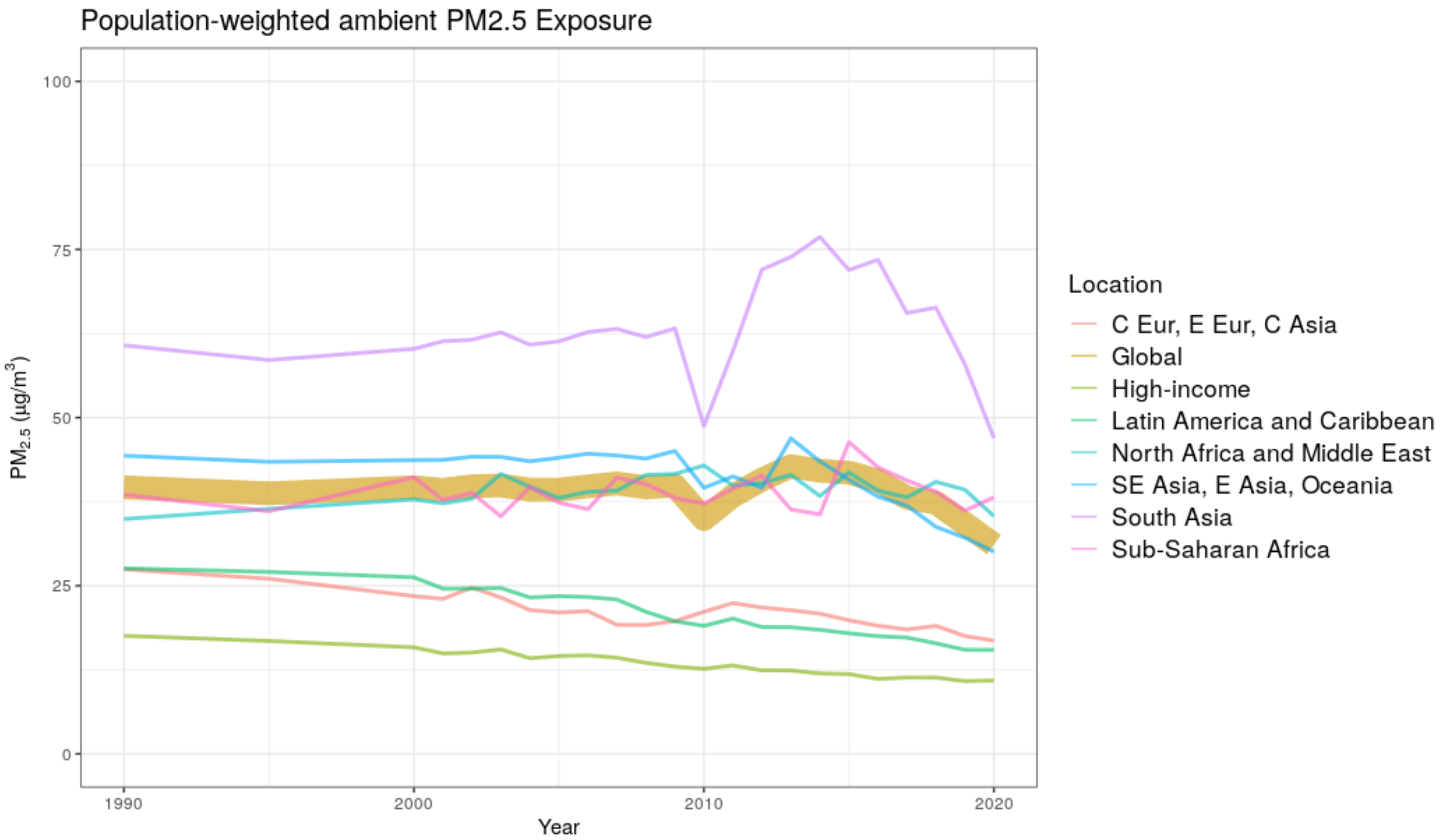
GBD 2021 evaluation:
Mean R^2 = 0.91 (95% UI 0.87 – 0.93)
Mean Pop-weighted RMSE = 8.5 (6.2 – 12.8) µg/m3

~11 x 11 km resolution (also 1 x 1 km) , annual average

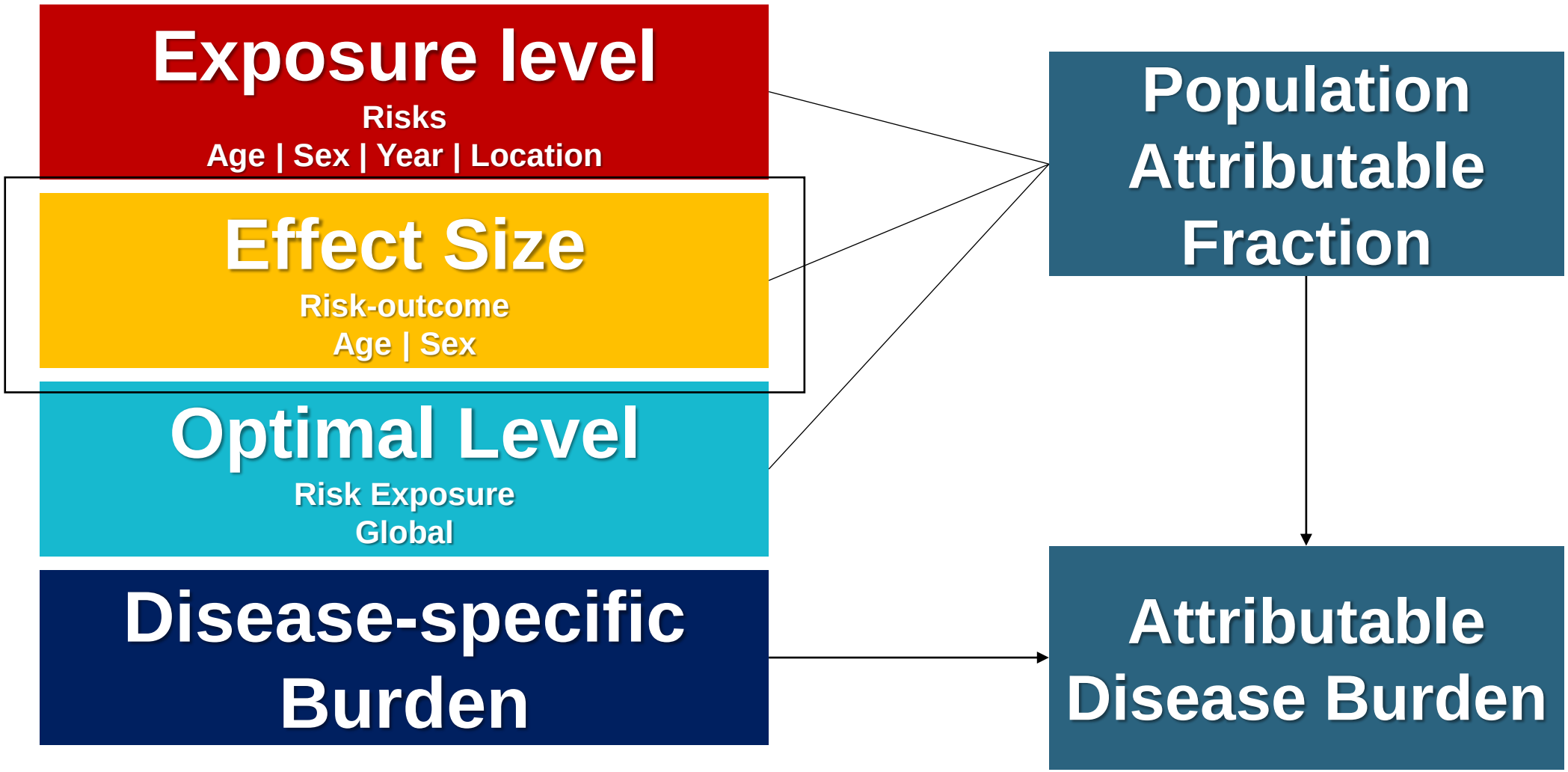
Shaddick et al. 2018. Data integration model for air quality: a hierarchical approach to the global estimation of exposures to ambient air pollution. J. R. Stat. Soc. C, 67: 231–253.
Shaddick et al. 2018. Data Integration for the Assessment of Population Exposure to Ambient Air Pollution for Global Burden of Disease Assessment. Environ Sci Technol. 2018 Aug 21;52(16):9069-9078.

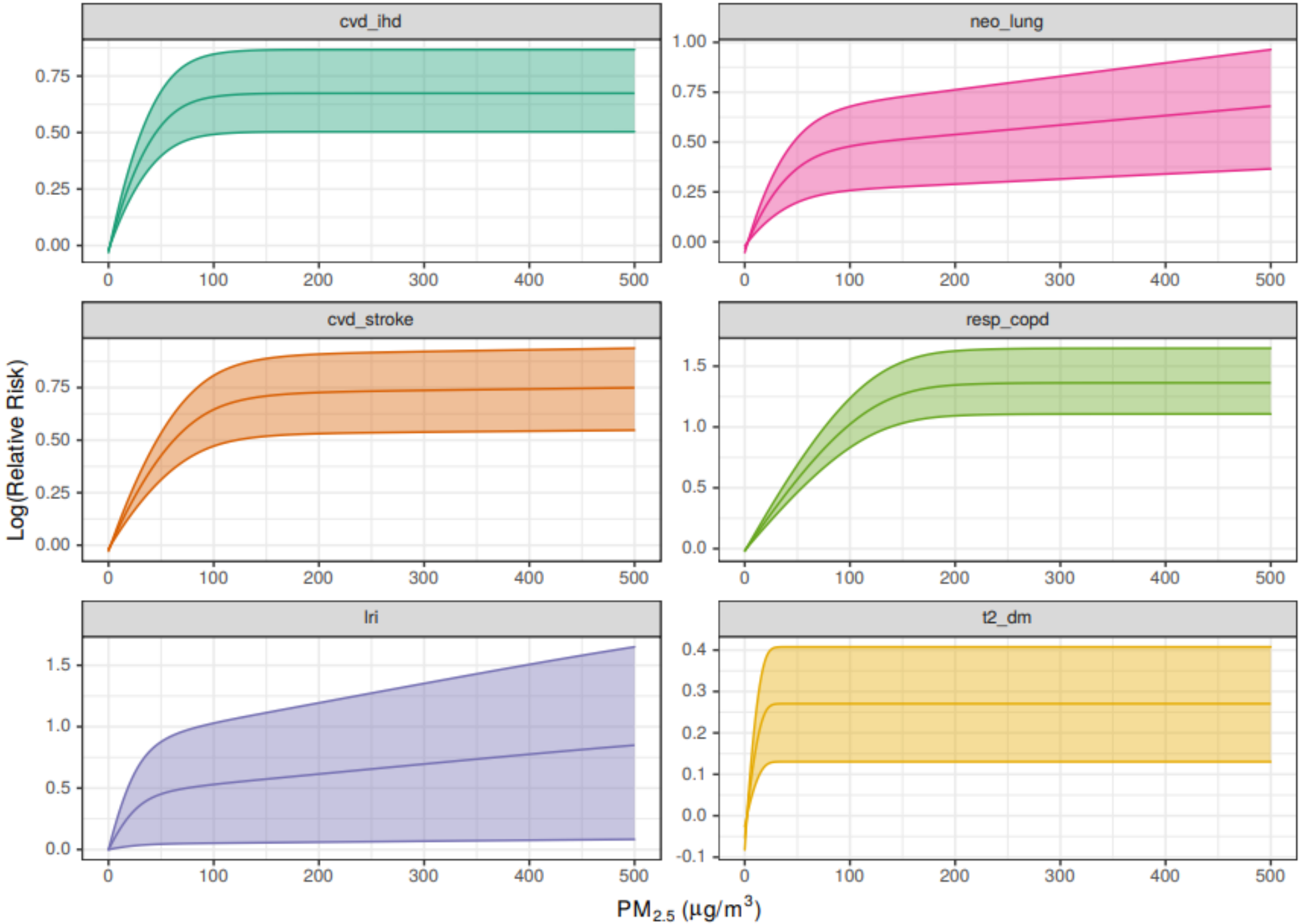
~Entire global population lives in areas > WHO AQG




Population-weighted ambient PM2.5 Exposure
100
75
50
25
0
PM2.5 (µg/m3)
1990
2000
2010
2020
Year
Location
C Eur, E Eur, C Asia
Global
High-income
Latin America and Caribbean
North Africa and Middle East
SE Asia, E Asia, Oceania
South Asia
Sub-Saharan Africa

Estimating disease burden from environmental risks




cvd_ihd
neo_lung
cvd_stroke
resp_copd
lri
t2_dm
Log(Relative Risk)
PM2.5 (µg/m3)

Robust assessment of the risk-outcome relationship

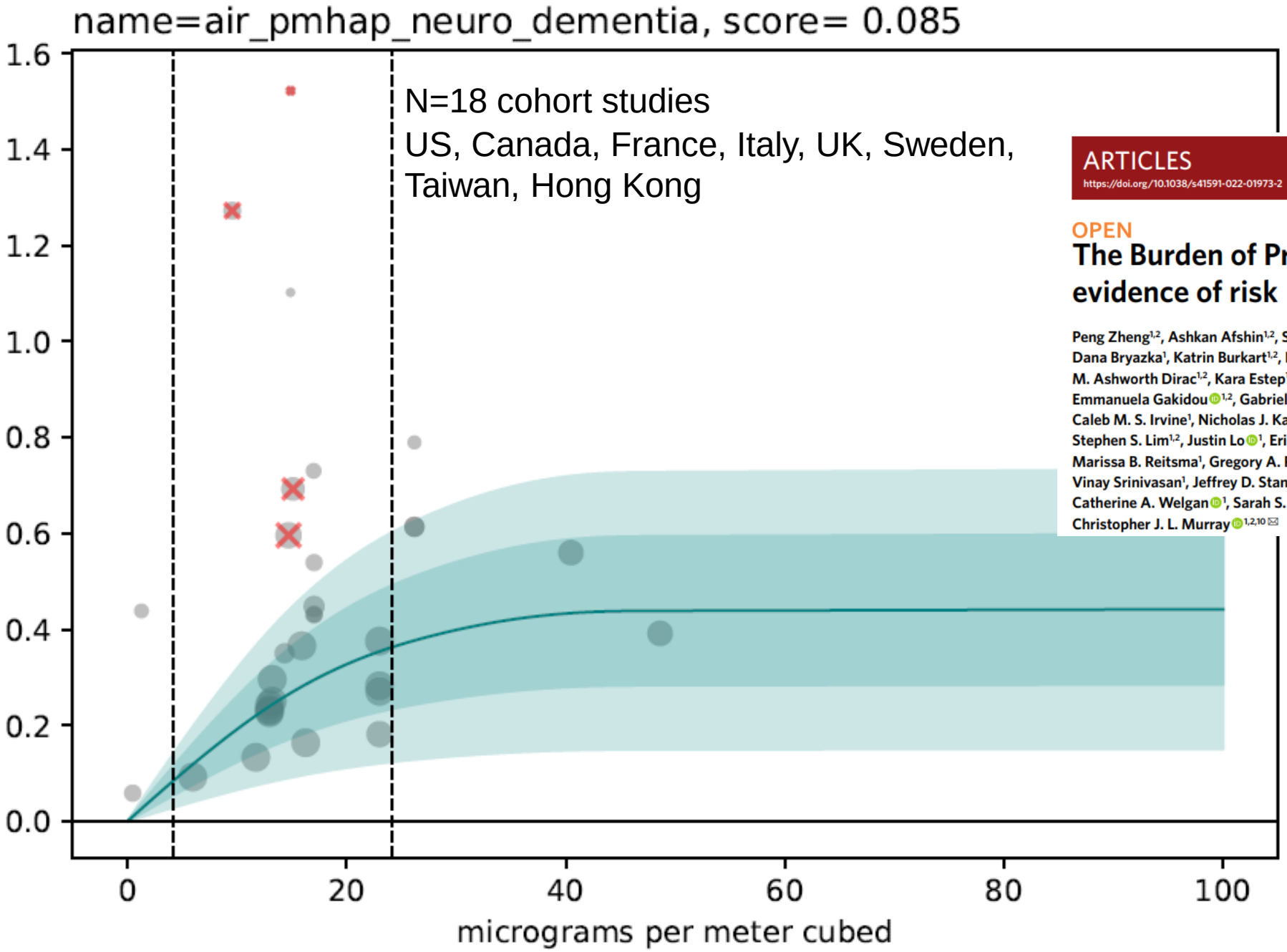
- **Meta-analysis or meta-regression** often used as an input.
- Many methods assume the relationship between exposure and risk is **log-linear**
- National or international guidelines typically come from **expert committees**
  - can consider nuances hard to capture in quantitative methods
  - different expert groups can and do arrive at different conclusions
- **GRADE** proposed to standardize issues. But GRADE is also subjective.

- Risk-outcome relationships with **small increases in risk** are more likely due to residual confounding or other biases.
- **Unexplained between-study heterogeneity** suggests uncaptured uncertainty

Burden of Proof Risk Function

- Smallest level of excess risk that is consistent with data.
- Incorporates:
  - **mean** relationship between risk and exposure in the available data
  - **unexplained* between study heterogeneity** adjusted for **number of studies**
    - *study design covariates (confounding, selection bias, exposure measurement, etc.)

Burden of Proof



ARTICLES
https://doi.org/10.1038/s41591-022-01973-2
nature medicine
Check for updates

OPEN

The Burden of Proof studies: assessing the evidence of risk

Peng Zheng[1,2], Ashkan Afshin[1,2], Stan Biryukov[1], Catherine Bisignano[1], Michael Brauer[1,2,3], Dana Bryazka[1], Katrin Burkart[1,2], Kelly M. Cercy[1], Leslie Cornaby[1], Xiaochen Dai[1,2], M. Ashworth Dirac[1,2], Kara Estep[1], Kairsten A. Fay[1], Rachel Feldman[1], Alize J. Ferrari[1,2,4,5], Emmanuela Gakidou[1,2], Gabriela Fernanda Gil[1], Max Griswold[1], Simon I. Hay[1,2], Jiawei He[1], Caleb M. S. Irvine[1], Nicholas J. Kassebaum[1,2,6], Kate E. LeGrand[1], Haley Lescinsky[1], Stephen S. Lim[1,2], Justin Lo[1], Erin C. Mullany[1], Kanyin Liane Ong[1], Puja C. Rao[1], Christian Razo[1], Marissa B. Reitsma[1], Gregory A. Roth[1,2,7], Damian F. Santomauro[1,2,4,5], Reed J. D. Sorensen[1], Vinay Srinivasan[1], Jeffrey D. Stanaway[1,2], Stein Emil Vollset[1,2], Theo Vos[1,2], Nelson Wang[8], Catherine A. Welgan[1], Sarah S. Wozniak[1], Aleksandr Y. Aravkin[1,2,9,10] and Christopher J. L. Murray[1,2,10] ✉

Data Visualization

Burden of Proof Risk Function

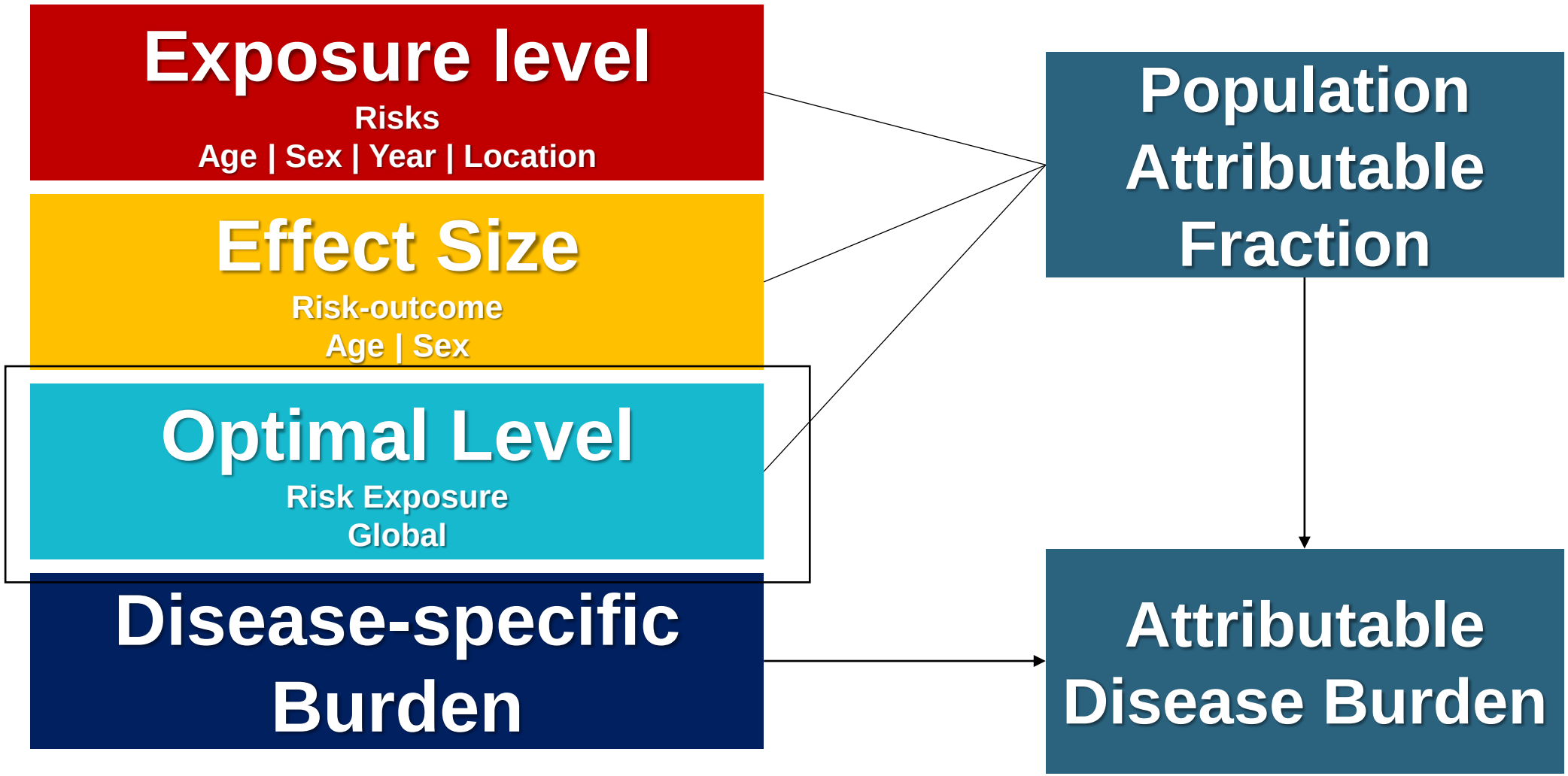
Risk Outcome Scores and Star Ratings

Weak evidence

Table 1. BPRF Risk-Outcome Score ranges associated with each star rating, and number of risk-outcome pairs assigned to each star rating.

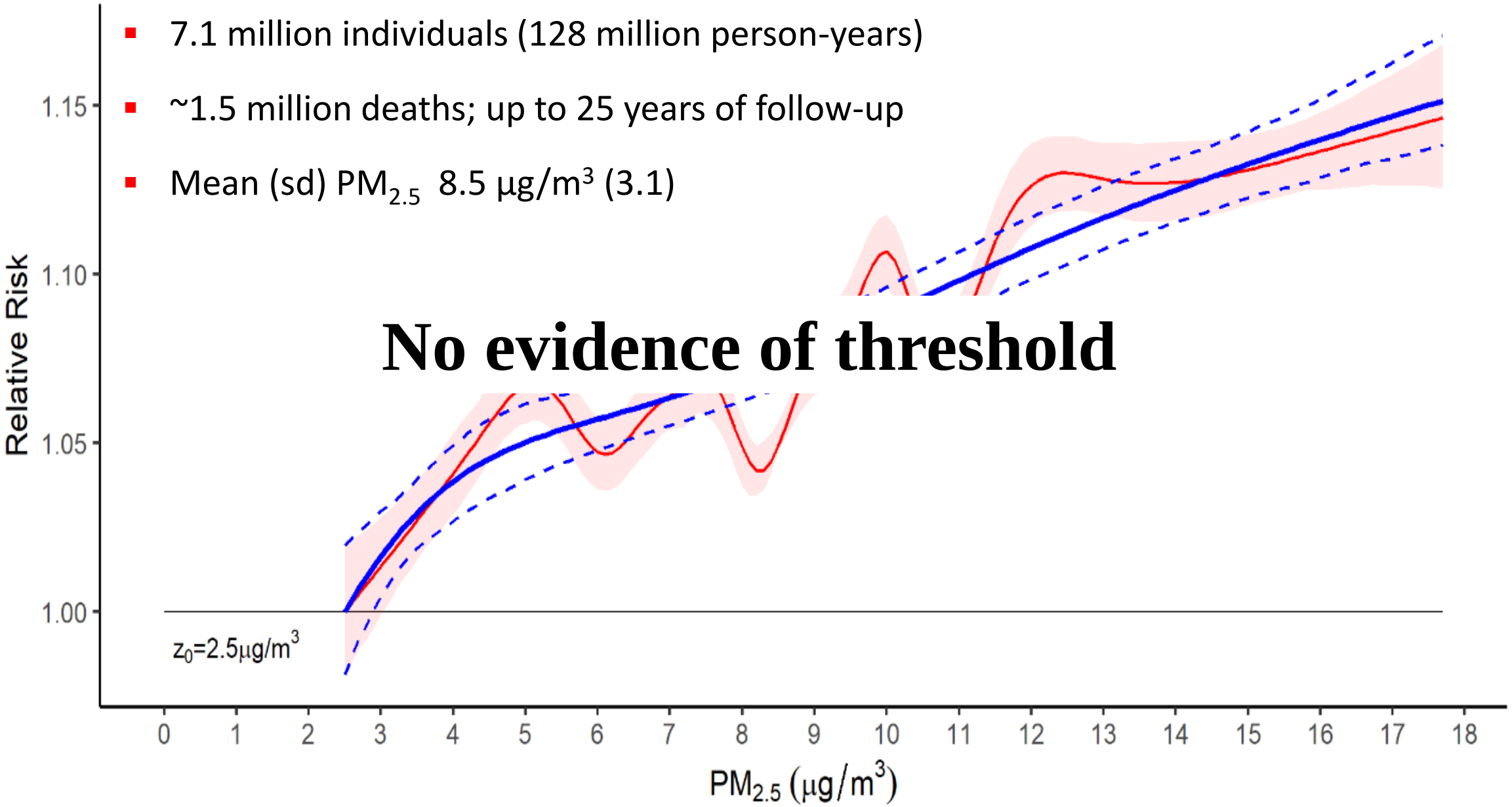
Star rating	Harmful - increases risk of outcome in those exposed by:	Protective – decreases risk of outcome in those exposed by:	ROS range	Number of R-O pairs (n = 211)
One star	0%	0%	<0.00	52
Two stars	0–15%	0–13%	0.00–0.14	79
Three stars	>15–50%	>13–34%	>0.14–0.41	55
Four stars	>50–85%	>34–46%	>0.41–0.62	13
Five stars	>85%	>46%	>0.62	12

Estimating disease burden from environmental risks



(A) Stacked Cohort (Non-Accidental): eSCHIF+r's(z_0) (blue), Ensemble RCS (red)

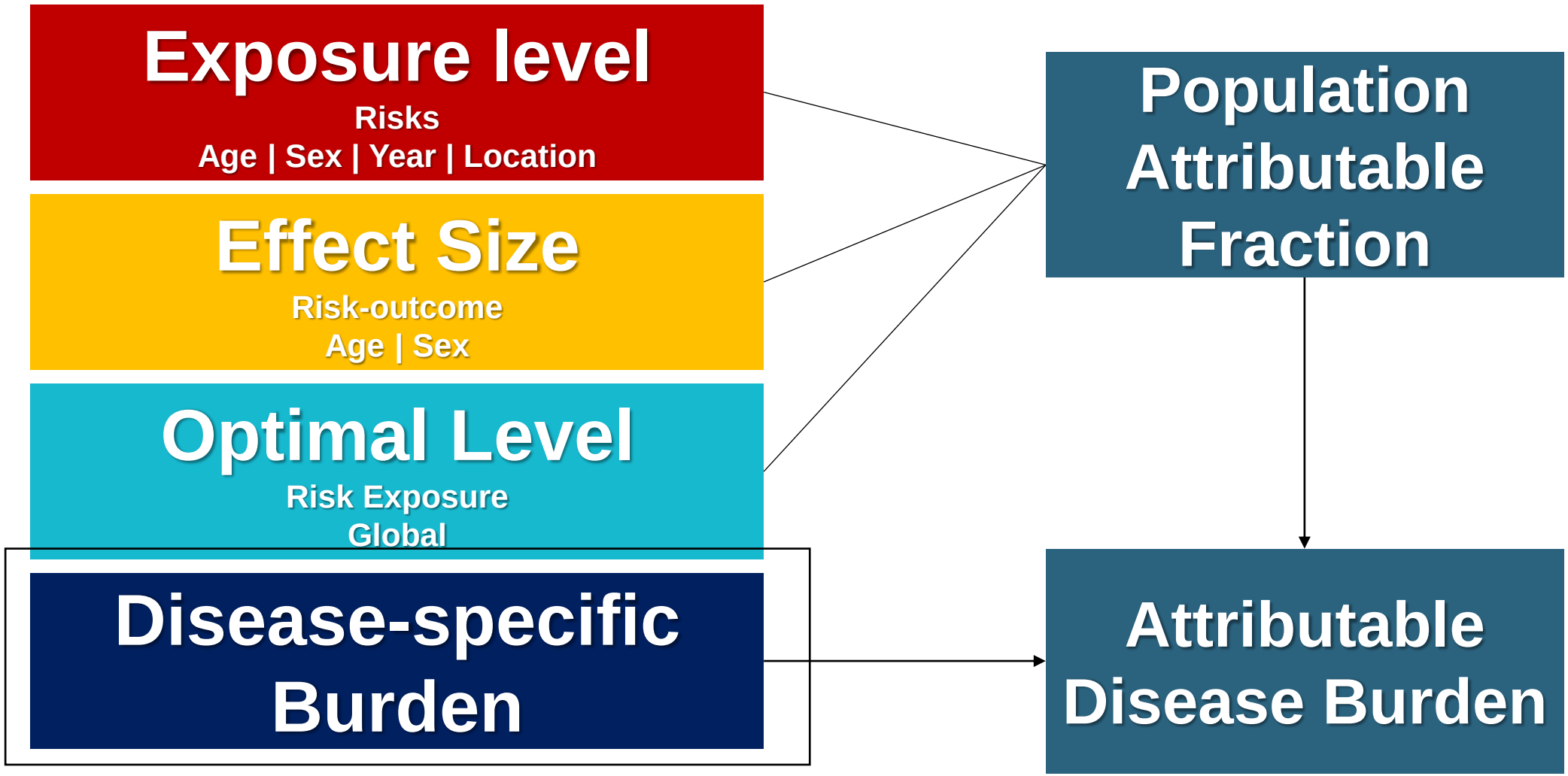
- 7.1 million individuals (128 million person-years)
- ~1.5 million deaths; up to 25 years of follow-up
- Mean (sd) $PM_{2.5}$ 8.5 µg/m^3 (3.1)



No evidence of threshold

https://www.healtheffects.org/publication/mortality-air-pollution-associations-low-exposure-environments-maple-phase-2

Estimating disease burden from environmental risks



Air pollution is the leading global environmental risk factor

2021

High blood pressure
Smoking
High fasting plasma glucose
Ambient particulate matter
High LDL
High BMI (adult)
Kidney dysfunction
Household air pollution
High sodium
High alcohol use
Low fruit
Lead (bone)
Low whole grains
Low birth weight
Low temperature
Secondhand smoke
Short gestation
Unsafe sex
Low vegetables
Unsafe water
Low PUFA
Low nuts and seeds
Low physical activity
Child underweight
Low omega-3
Low fiber
Occupational particulates
Unsafe sanitation
Child wasting
Ozone
Occupational injury
Low bone mineral density
Handwashing
Injected drug use
High temperature

4.8 M deaths ~7% of all deaths

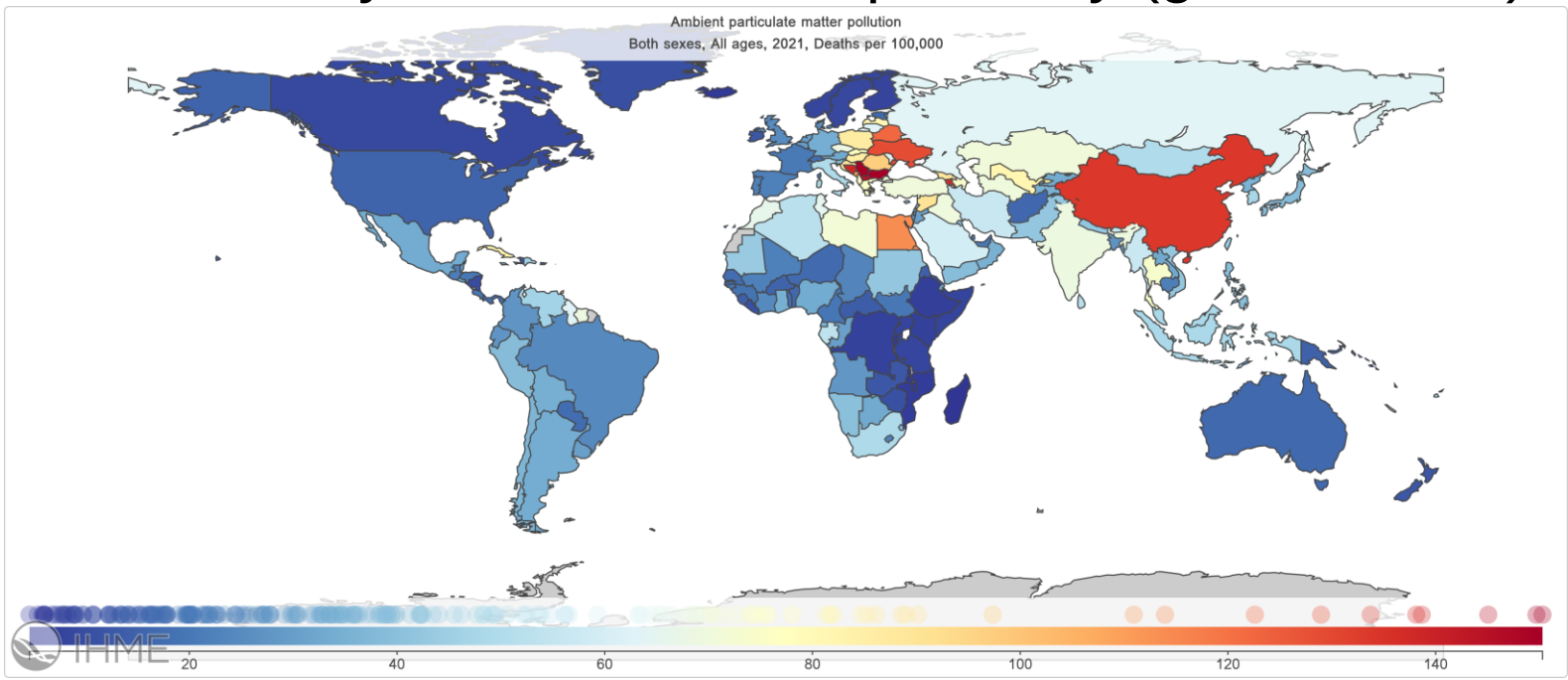
3.5 M deaths

500K deaths

$5 trillion/yr welfare losses

$225 billion/yr lost labour income

` 1 year loss of life expectancy (global mean)



0
2M
4M
6M
8M
10M
Deaths

IHME

World Bank. 2016. *The cost of air pollution : strengthening the economic case for action*

88 risk factors

Metabolic risks

Level	Risks
1	Metabolic risks
2	High fasting plasma glucose
2	High total cholesterol
2	High systolic blood pressure
2	High body mass index
2	Low bone mineral density
2	Impaired kidney function

Environmental/occupational risks

Level	Risks
1	Environmental/occupational risks
2	Unsafe water, sanitation, and handwashing
3	Unsafe water source
3	Unsafe sanitation
3	No access to handwashing facility
2	Air pollution
3	Particulate matter pollution
4	Ambient particulate matter pollution
4	Household air pollution from solid fuels
3	Ambient ozone pollution
3	Nitrogen Dioxide Air pollution
2	Non-optimal temperature
3	Low temperature
3	High temperature
2	Other environmental risks
3	Residential radon
3	Lead exposure
2	Occupational risks
3	Occupational carcinogens
4	Occupational exposure to arsenic
4	Occupational exposure to asbestos
4	Occupational exposure to benzene
4	Occupational exposure to beryllium
4	Occupational exposure to cadmium
4	Occupational exposure to chromium
4	Occupational exposure to diesel engine exhaust
4	Occupational exposure to formaldehyde
4	Occupational exposure to nickel
4	Occupational exposure to polycyclic aromatic hydrocarbons
4	Occupational exposure to secondhand smoke
4	Occupational exposure to silica
4	Occupational exposure to sulfuric acid
4	Occupational exposure to trichloroethylene
3	Occupational asthmagens
3	Occupational ergonomic factors
3	Occupational injuries
3	Occupational noise
3	Occupational particulate matter, gases, and fumes

Behavioral risks

Level	Risks
1	Behavioral risks
2	Child and maternal malnutrition
3	Suboptimal breastfeeding
4	Non-exclusive breastfeeding
4	Discontinued breastfeeding
3	Child growth failure
4	Child underweight
4	Child wasting
4	Child stunting
3	Low birth weight and short gestation
4	Short gestation for birth weight
4	Low birth weight for gestation
3	Iron deficiency
3	Vitamin A deficiency
3	Zinc deficiency
2	Tobacco
3	Smoking
3	Smokeless tobacco
3	Secondhand smoke
2	Alcohol and drug use
3	Alcohol use
3	Drug use
2	Dietary risks
3	Diet high in processed meat
3	Diet high in red meat
3	Diet high in sodium
3	Diet high in sugar-sweetened beverages
3	Diet high in trans fatty acids
3	Diet low in calcium
3	Diet low in fiber
3	Diet low in fruits
3	Diet low in legumes
3	Diet low in milk
3	Diet low in nuts and seeds
3	Diet low in polyunsaturated fatty acids
3	Diet low in seafood omega-3 fatty acids
3	Diet low in vegetables
3	Diet low in whole grains
2	Sexual abuse and violence
3	Childhood sexual abuse
3	Intimate partner violence
2	Unsafe sex
2	Low physical activity

Results

Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021

*GBD 2021 Risk Factors Collaborators**

Lancet 2024; 403: 2162–203

See **Comment** page 1960

*Collaborators listed at the end of the Article

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Prof Simon I Hay, Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA 98195, USA
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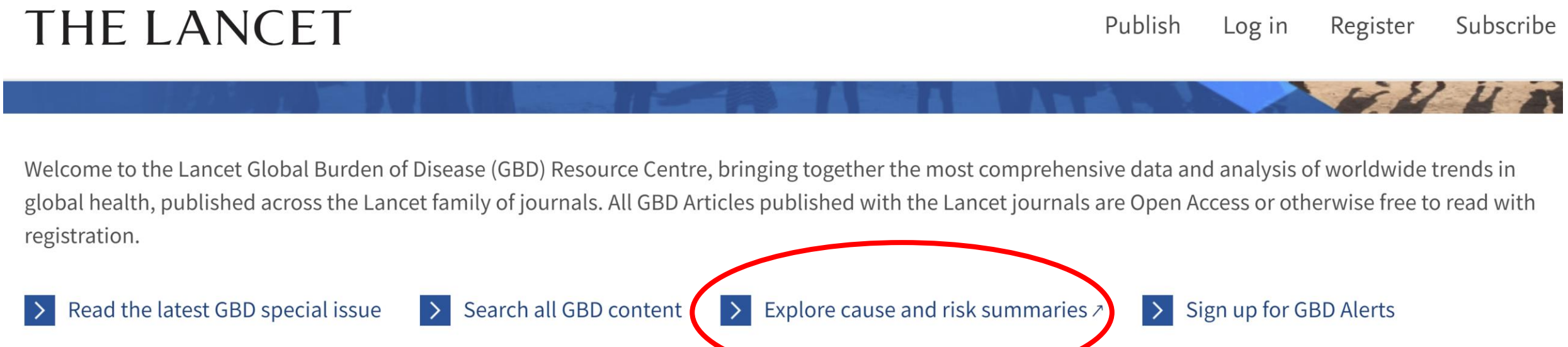
Summary

Background Understanding the health consequences associated with exposure to risk factors is necessary to inform public health policy and practice. To systematically quantify the contributions of risk factor exposures to specific health outcomes, the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 aims to provide comprehensive estimates of exposure levels, relative health risks, and attributable burden of disease for 88 risk factors in 204 countries and territories and 811 subnational locations, from 1990 to 2021.

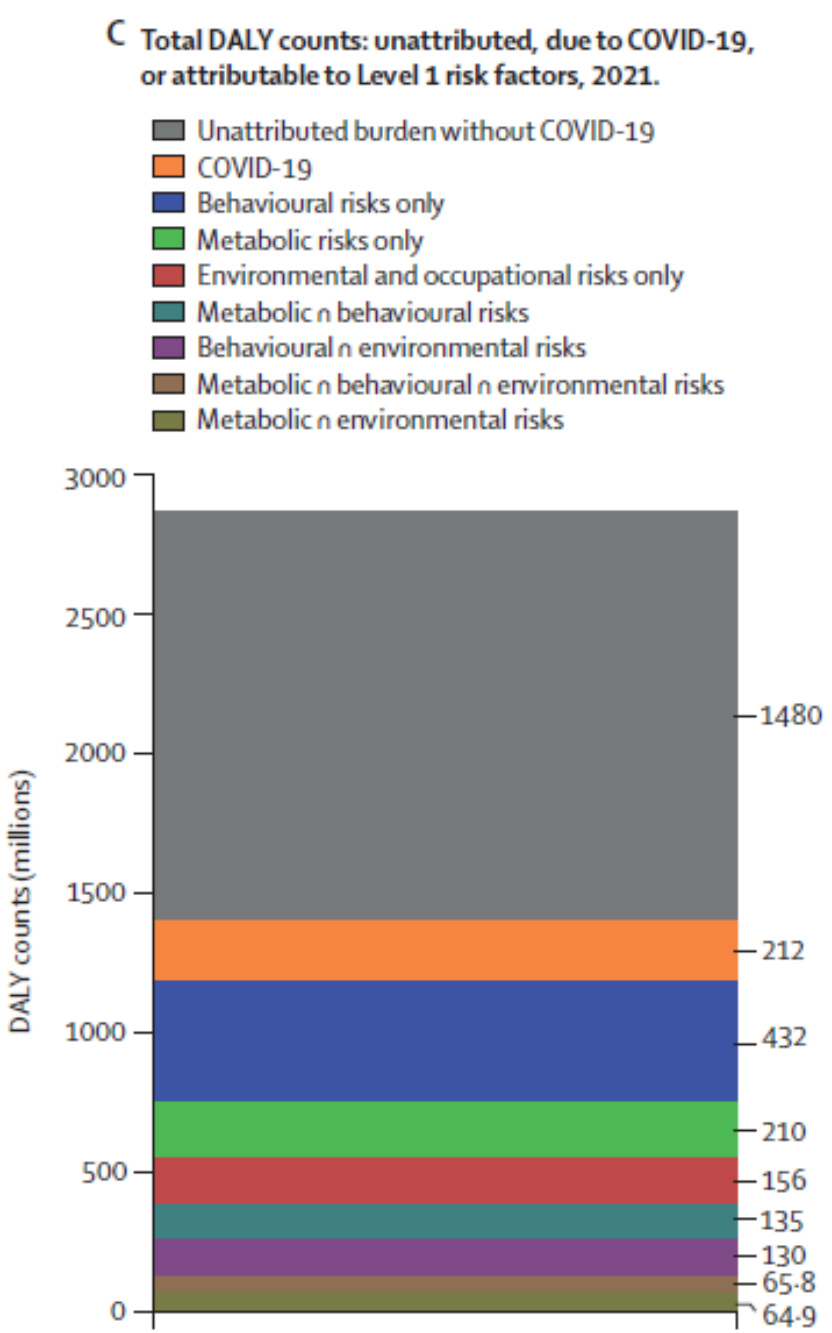
Methods The GBD 2021 risk factor analysis used data from 54 561 total distinct sources to produce epidemiological estimates for 88 risk factors and their associated health outcomes for a total of 631 risk–outcome pairs. Pairs were included on the basis of data-driven determination of a risk–outcome association. Age-sex-location-year-specific estimates were generated at global, regional, and national levels. Our approach followed the comparative risk

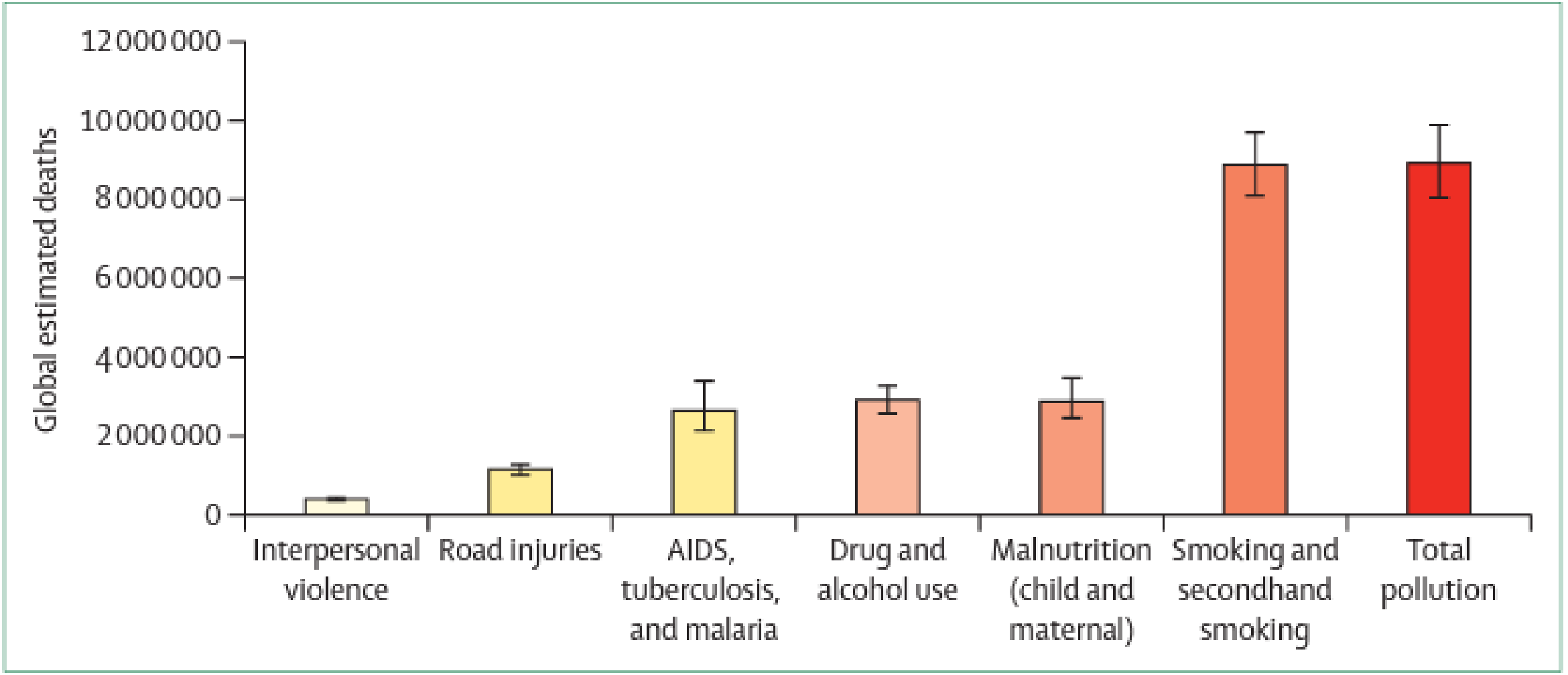
https://www.thelancet.com/gbd

2-page Risk Factor and Cause Summaries



- 88 risk factors
- 155 outcomes
- 631 risk–outcome pairs
- 41·4% global DALYs attributable risk factors
  - 14.4 % Environmental/Occupational
    - 18.9% (12.8 million) of all deaths
  - 7·4% of DALYs due to COVID

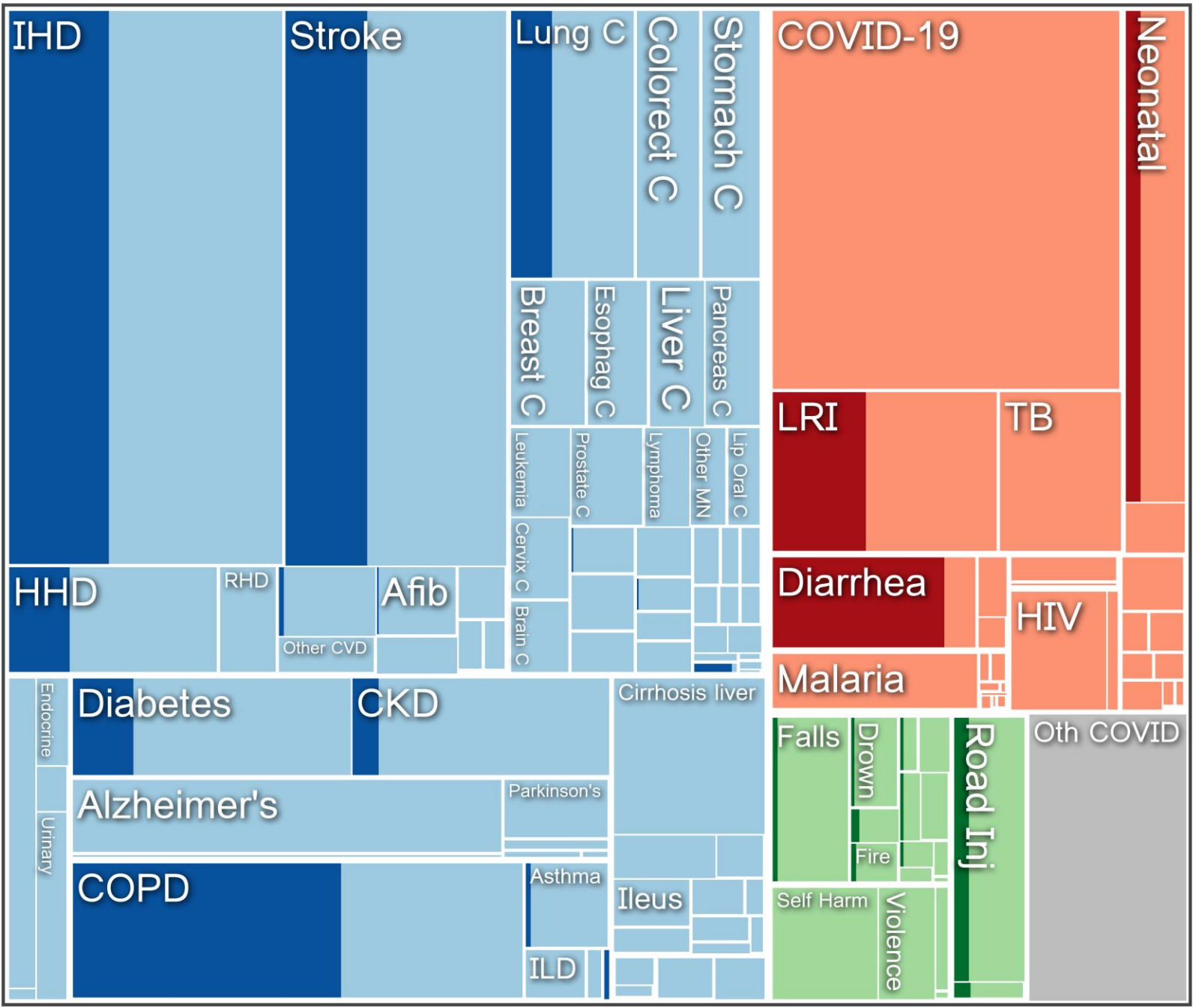




Pollution and health: a progress update. Lancet Planetary Health, 2022. https://doi.org/10.1016/S2542-5196(22)00090-0

Global

Both sexes, All ages, 2021, Deaths attributable to Environmental/occupational risks

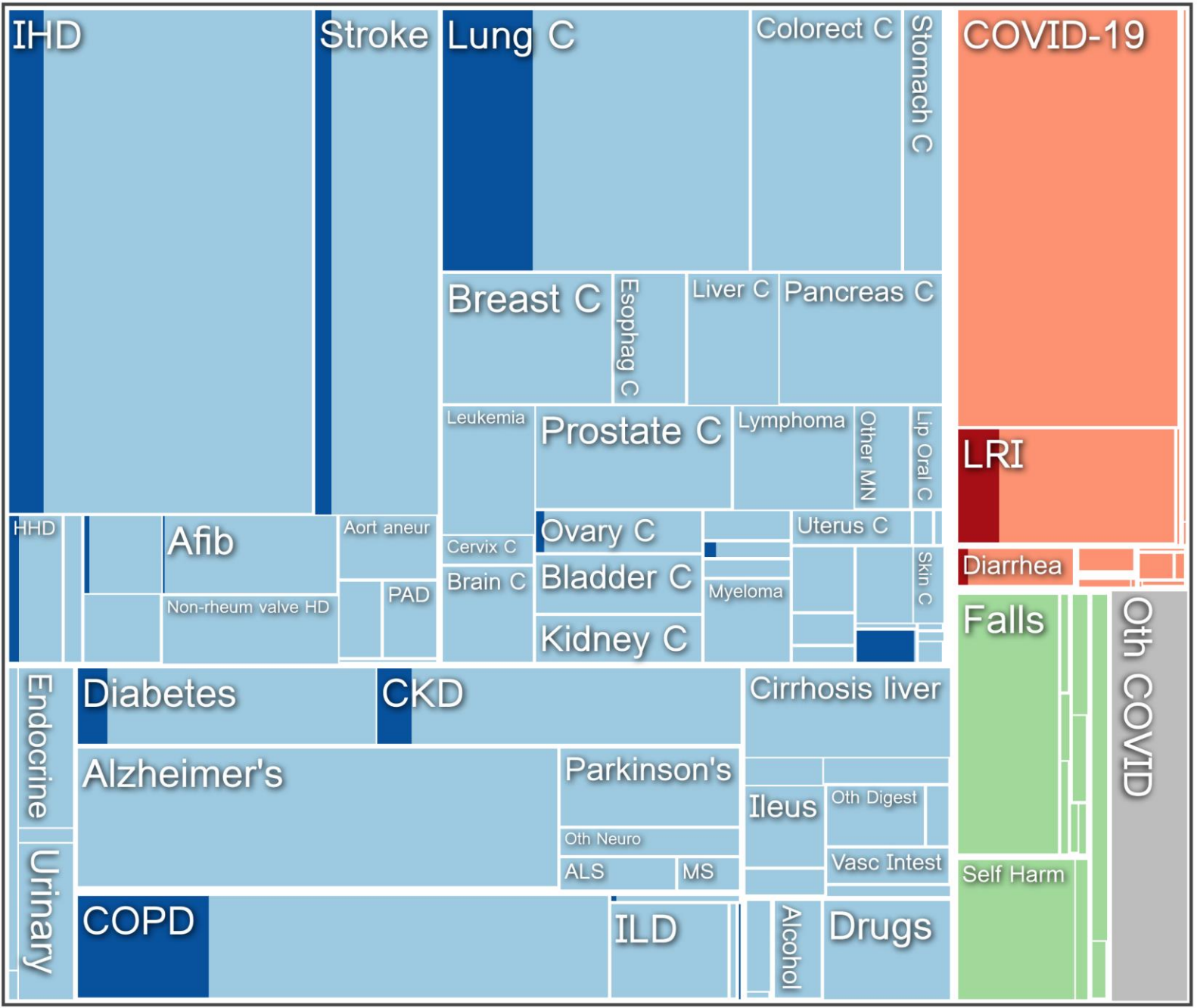


Deaths attributable to risk

Deaths not attributable to risk

Canada

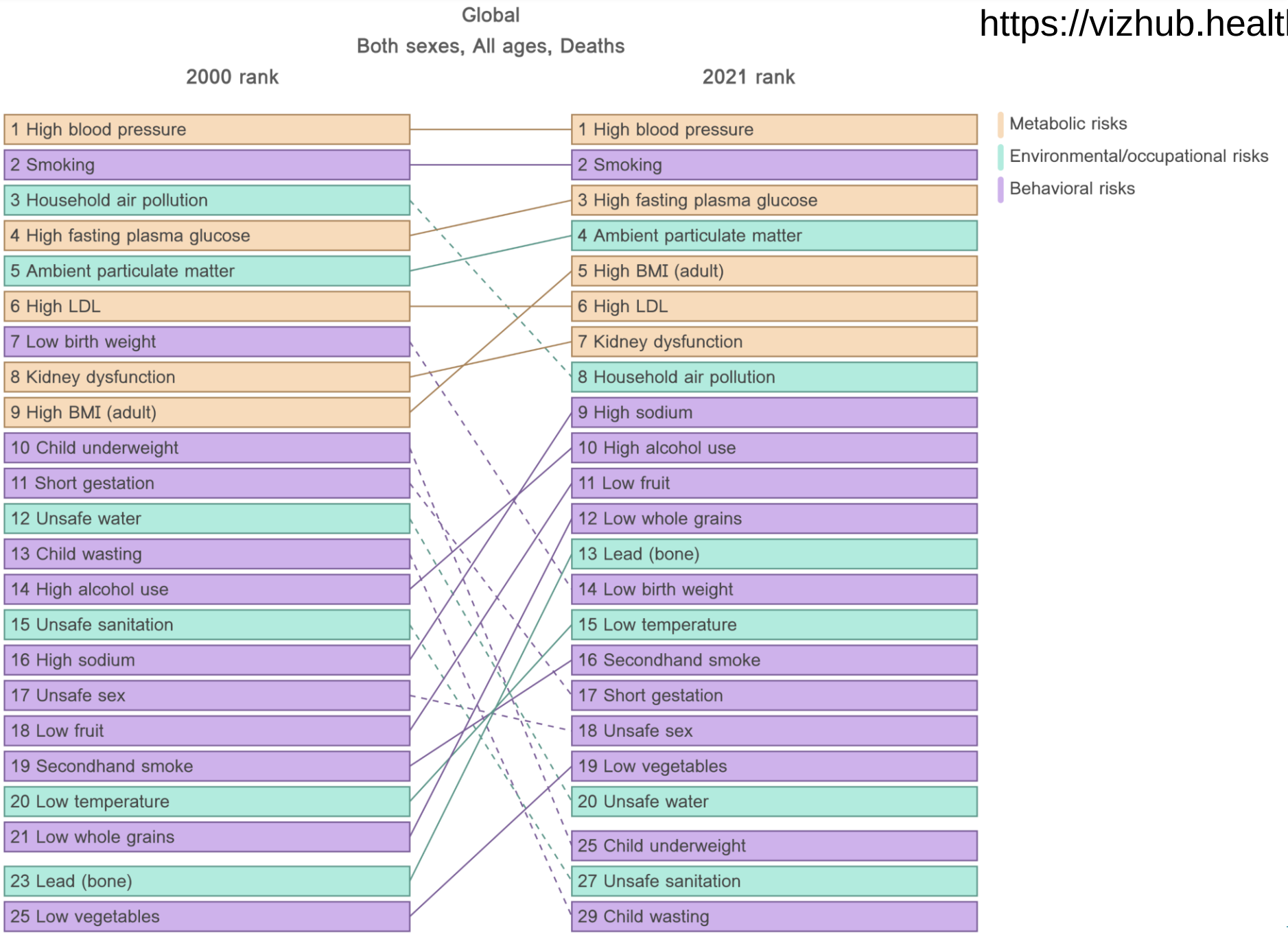
Both sexes, All ages, 2021, Deaths attributable to Environmental/occupational risks



Deaths attributable to risk

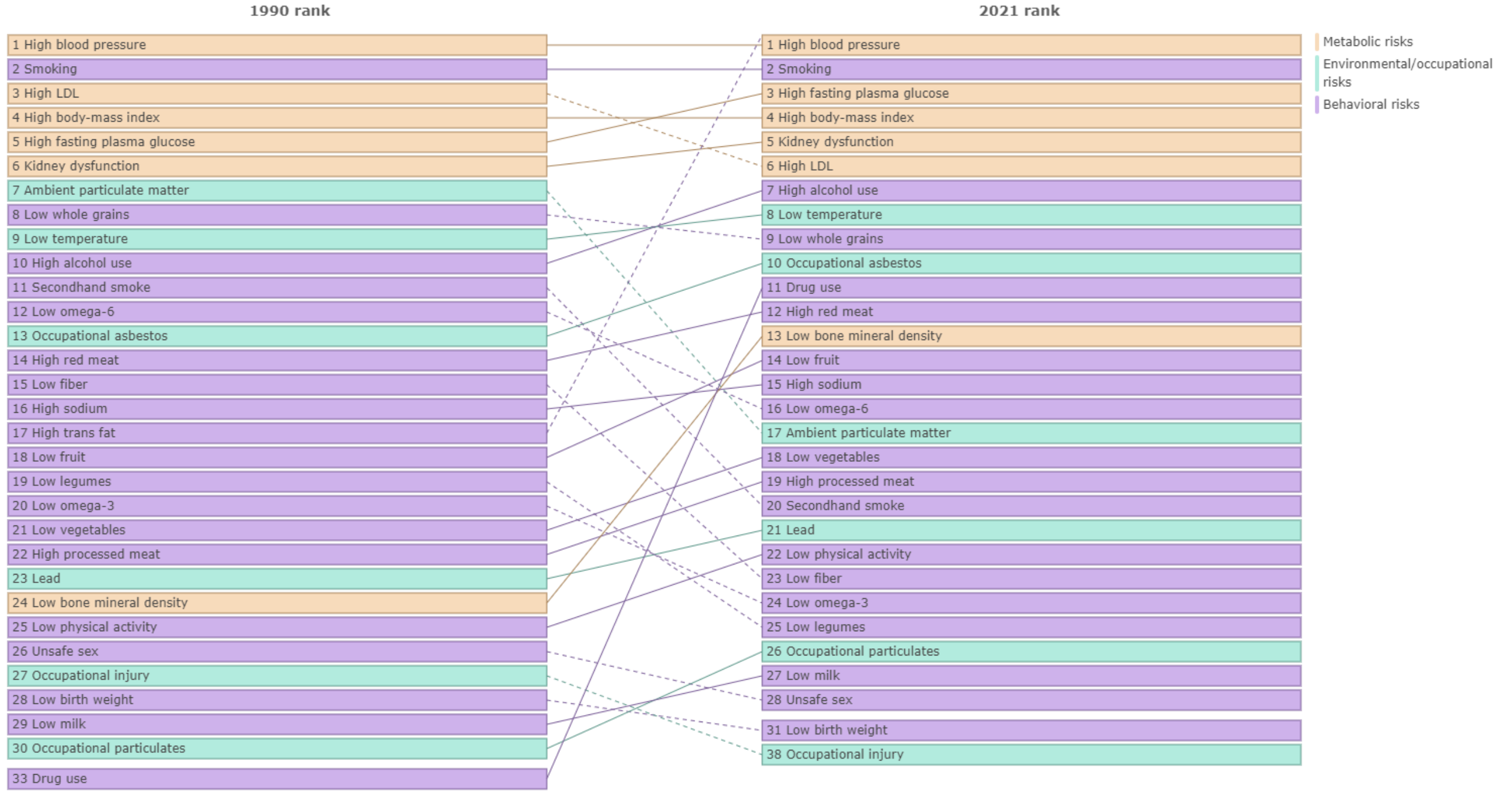
Deaths not attributable to risk

https://vizhub.healthdata.org/gbd-compare/

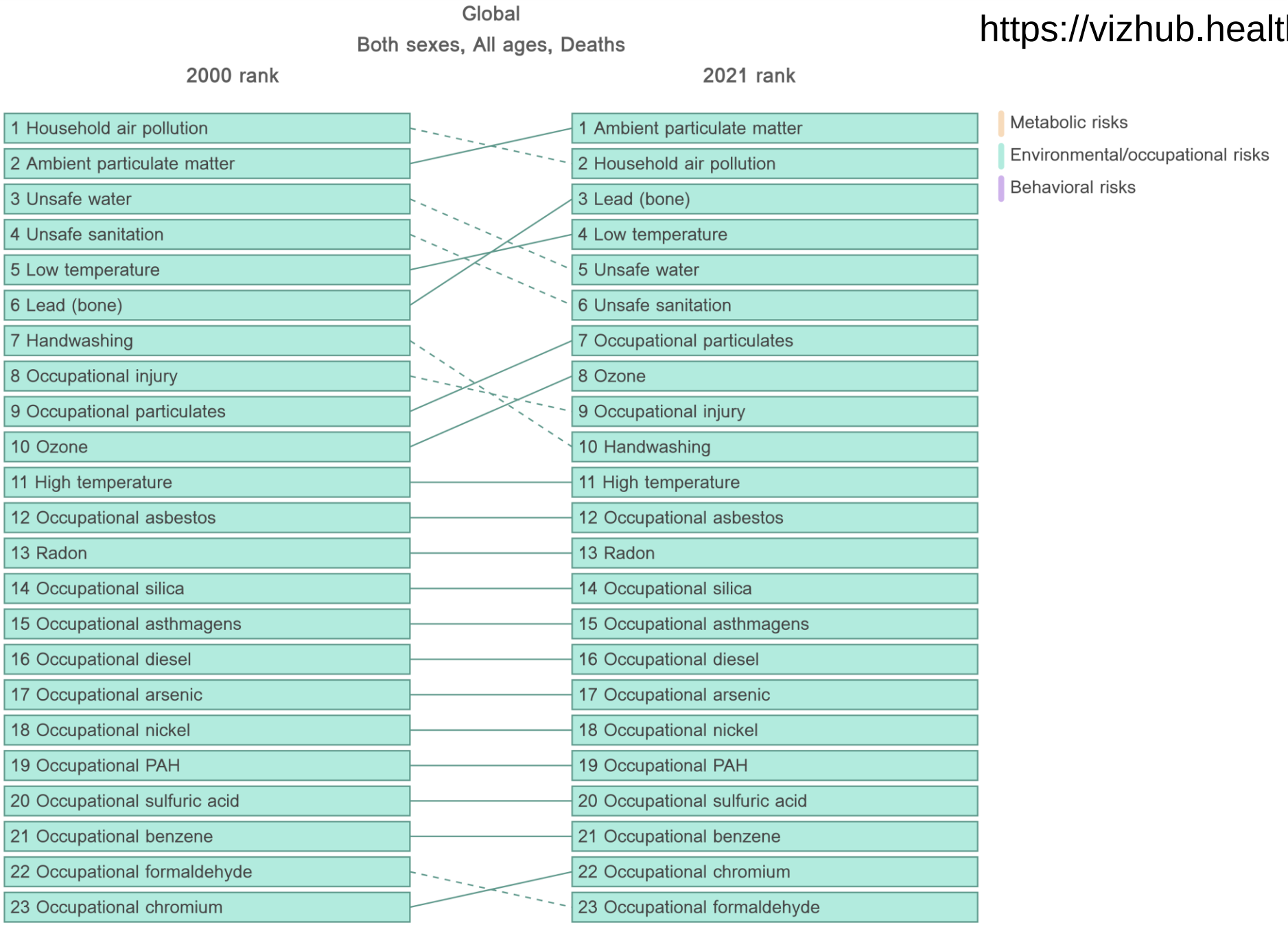


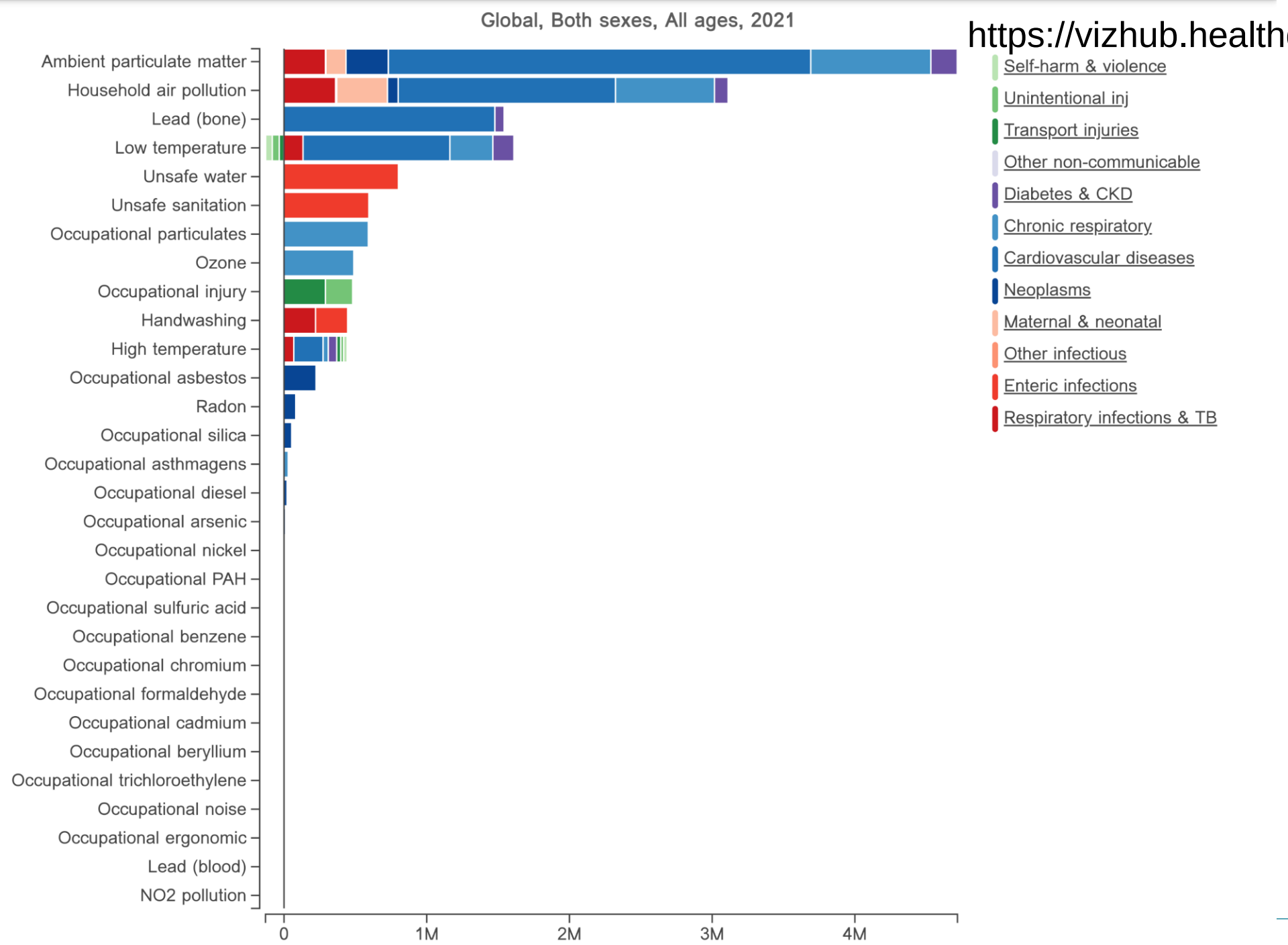
Canada

Both sexes, All ages, Deaths



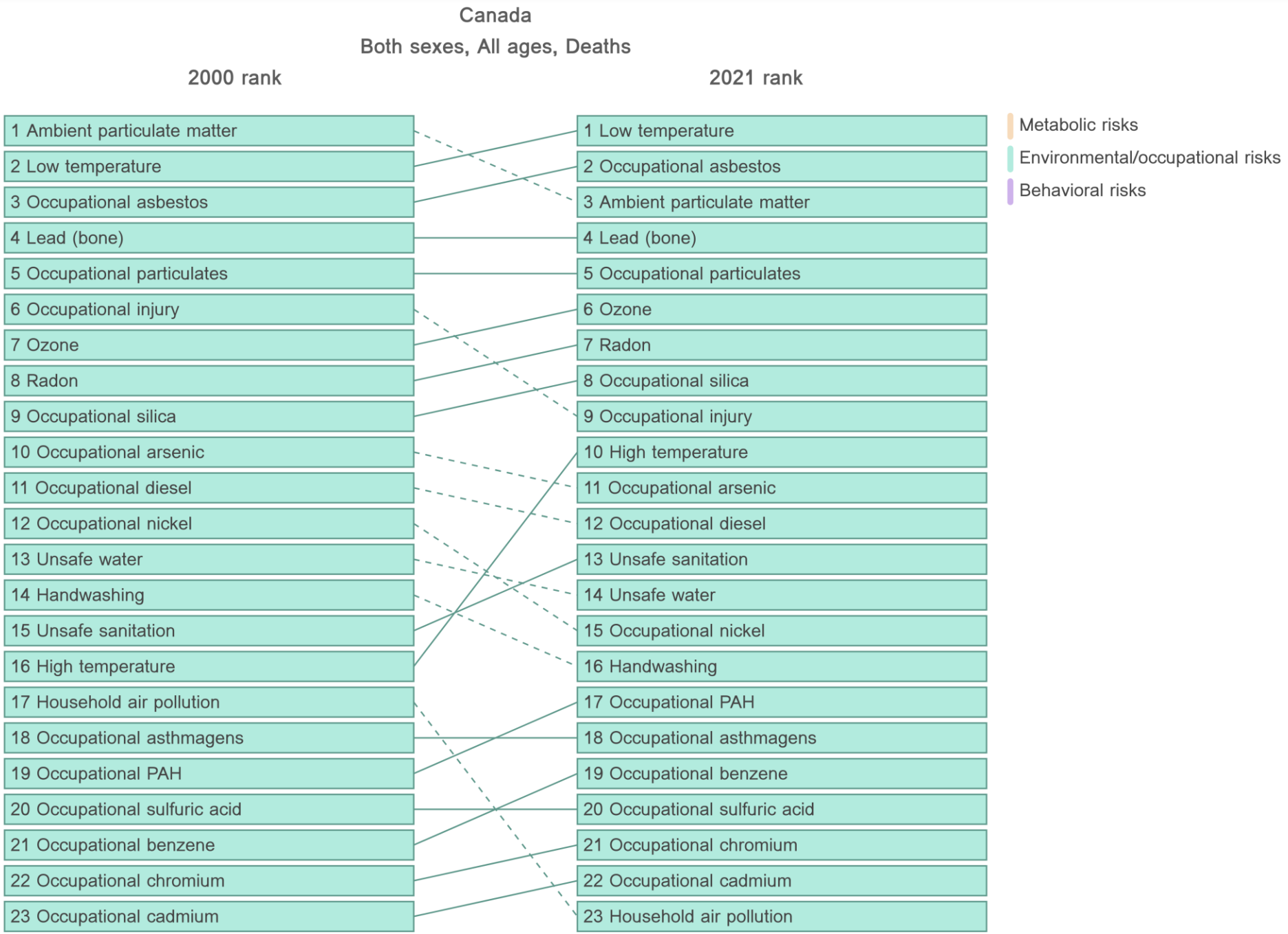
https://vizhub.healthdata.org/gbd-compare/

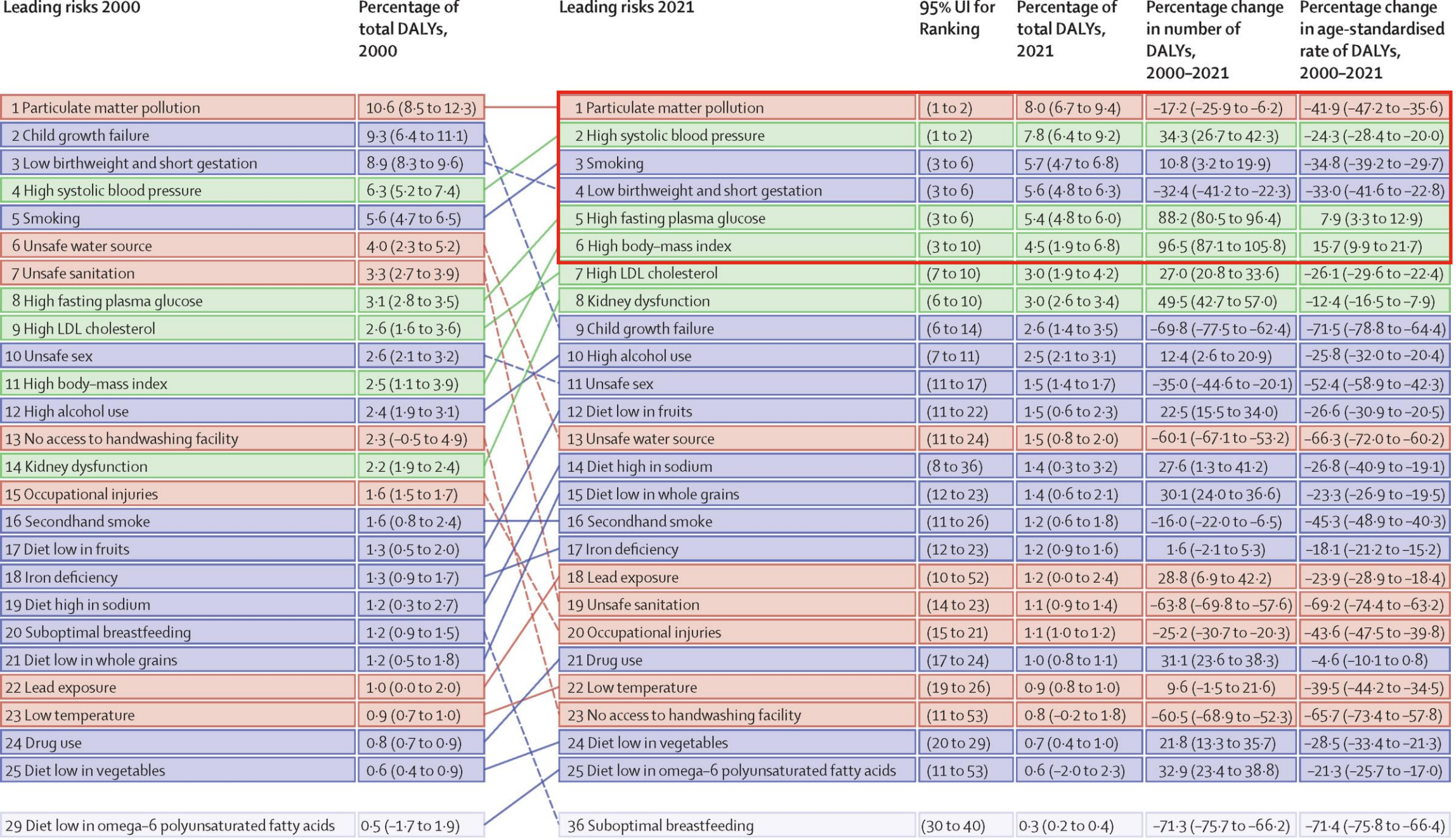




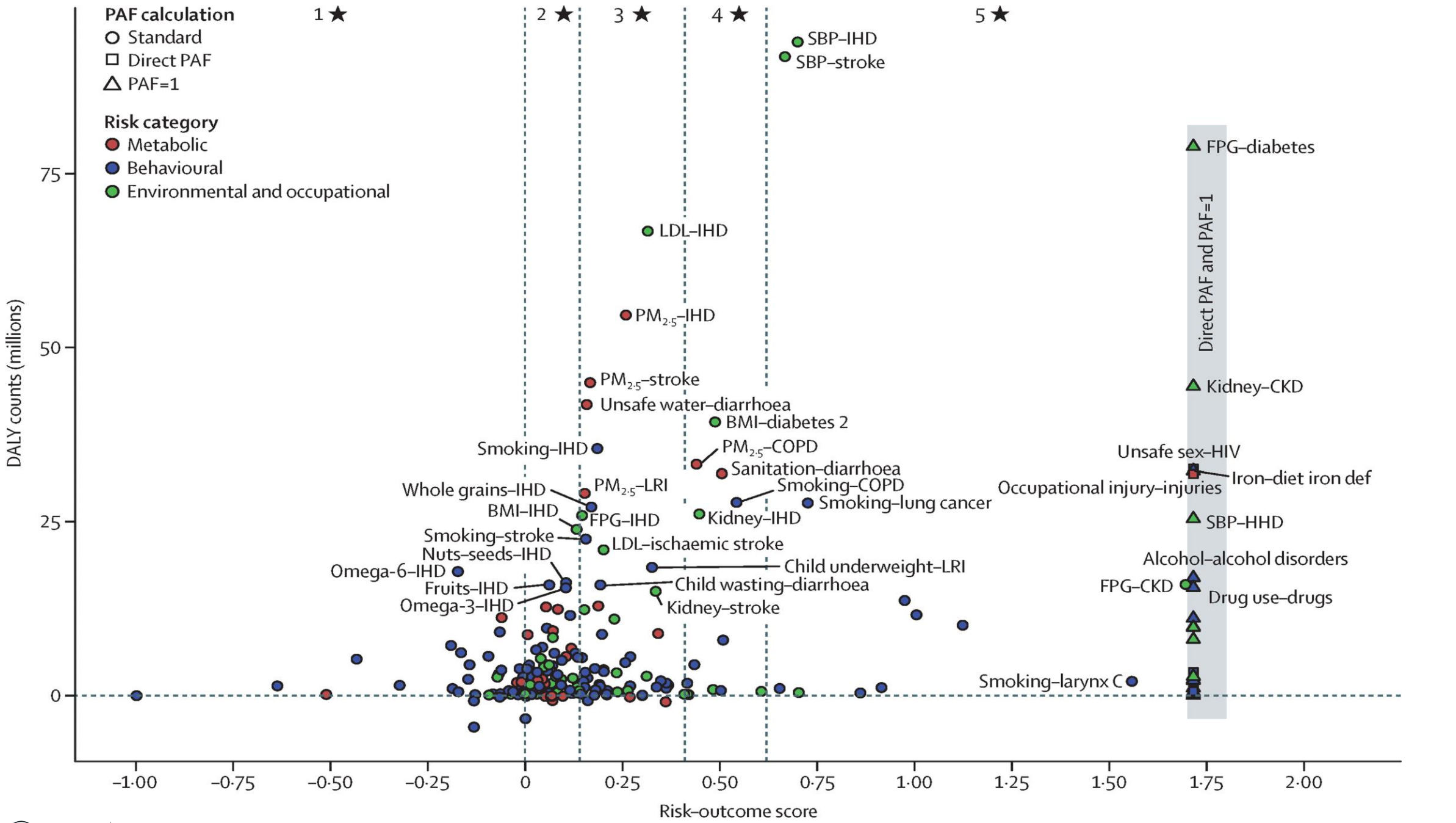
https://vizhub.healthdata.org/gbd-compare/

- Self-harm & violence
- Unintentional inj
- Transport injuries
- Other non-communicable
- Diabetes & CKD
- Chronic respiratory
- Cardiovascular diseases
- Neoplasms
- Maternal & neonatal
- Other infectious
- Enteric infections
- Respiratory infections & TB


Canada
Both sexes, All ages, Deaths
2000 rank
2021 rank
1 Ambient particulate matter
2 Low temperature
3 Occupational asbestos
4 Lead (bone)
5 Occupational particulates
6 Occupational injury
7 Ozone
8 Radon
9 Occupational silica
10 Occupational arsenic
11 Occupational diesel
12 Occupational nickel
13 Unsafe water
14 Handwashing
15 Unsafe sanitation
16 High temperature
17 Household air pollution
18 Occupational asthmagens
19 Occupational PAH
20 Occupational sulfuric acid
21 Occupational benzene
22 Occupational chromium
23 Occupational cadmium
1 Low temperature
2 Occupational asbestos
3 Ambient particulate matter
4 Lead (bone)
5 Occupational particulates
6 Ozone
7 Radon
8 Occupational silica
9 Occupational injury
10 High temperature
11 Occupational arsenic
12 Occupational diesel
13 Unsafe sanitation
14 Unsafe water
15 Occupational nickel
16 Handwashing
17 Occupational PAH
18 Occupational asthmagens
19 Occupational benzene
20 Occupational sulfuric acid
21 Occupational chromium
22 Occupational cadmium
23 Household air pollution
Metabolic risks
Environmental/occupational risks
Behavioral risks



Brauer M et al. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024 May



Brauer M et al. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024 May

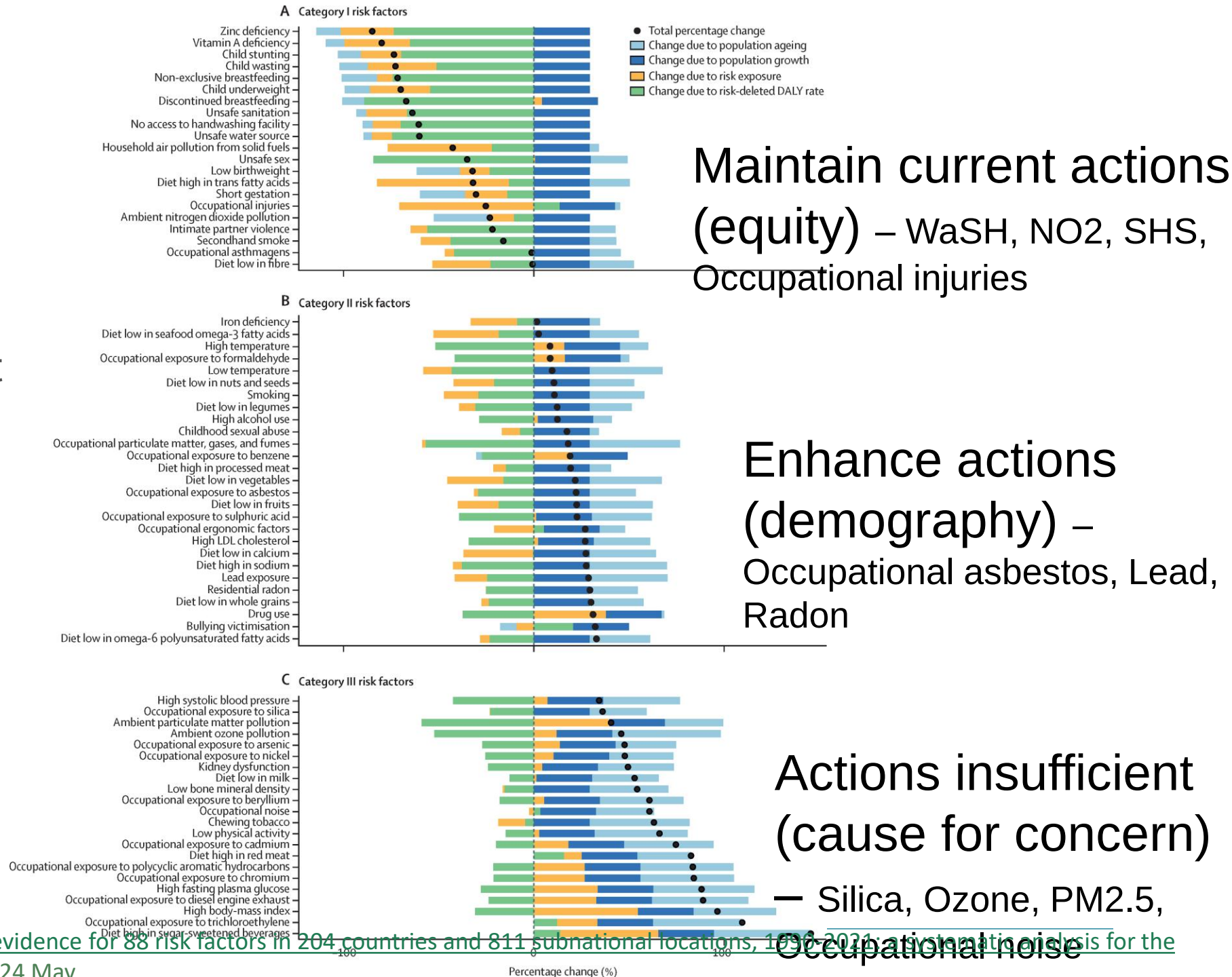
Implications

Ambient PM2.5, SBP, smoking, FPG (all SDI)

Low birthweight/ short gestation (low SDI)

BMI (high SDI).

Metabolic syndrome (FPG, SBP, physical inactivity, sugar-sweetened beverages)



Maintain current actions (equity) – WaSH, NO2, SHS, Occupational injuries

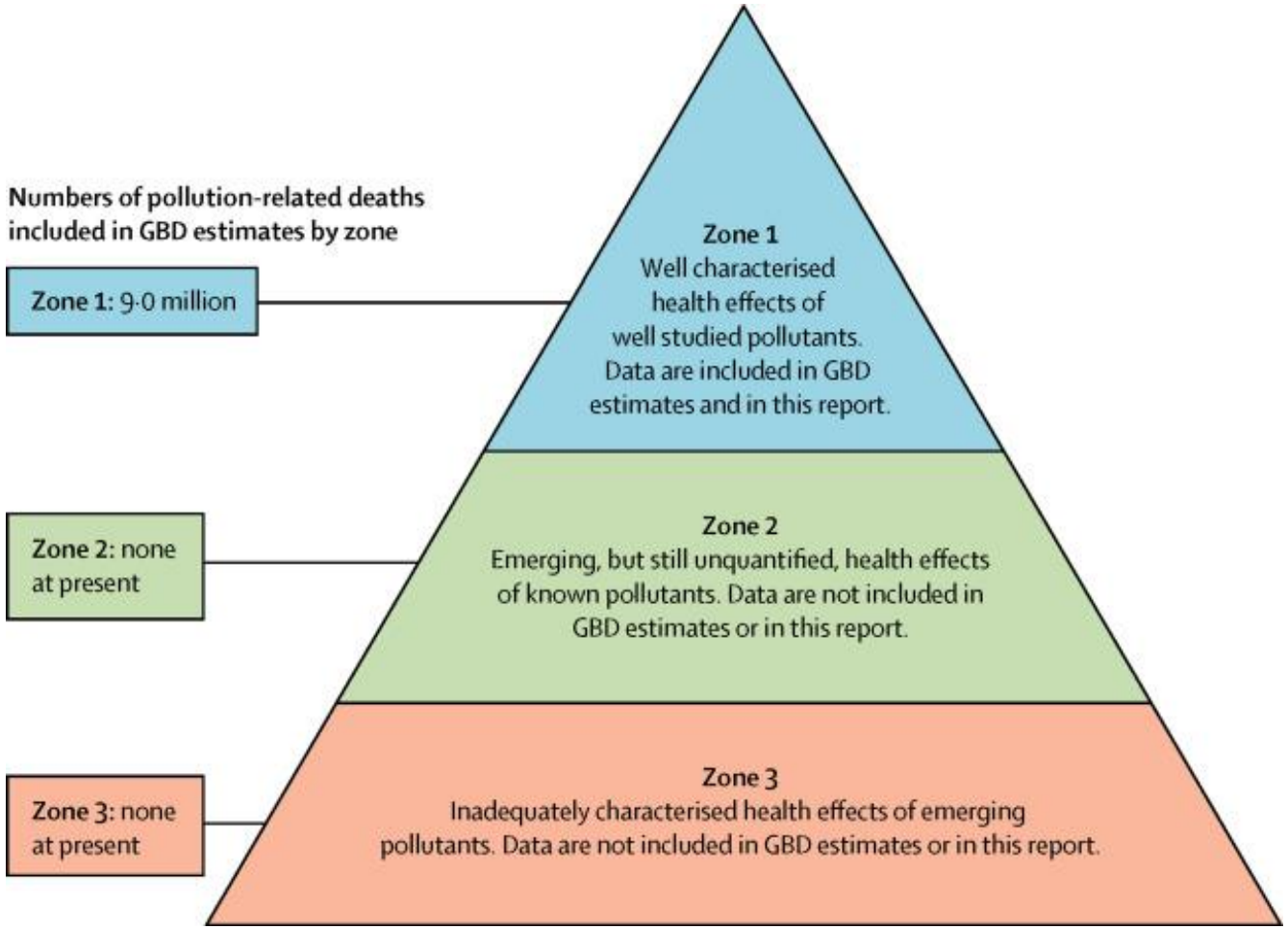
Enhance actions (demography) – Occupational asbestos, Lead, Radon

Actions insufficient (cause for concern) – Silica, Ozone, PM2.5, Occupational noise

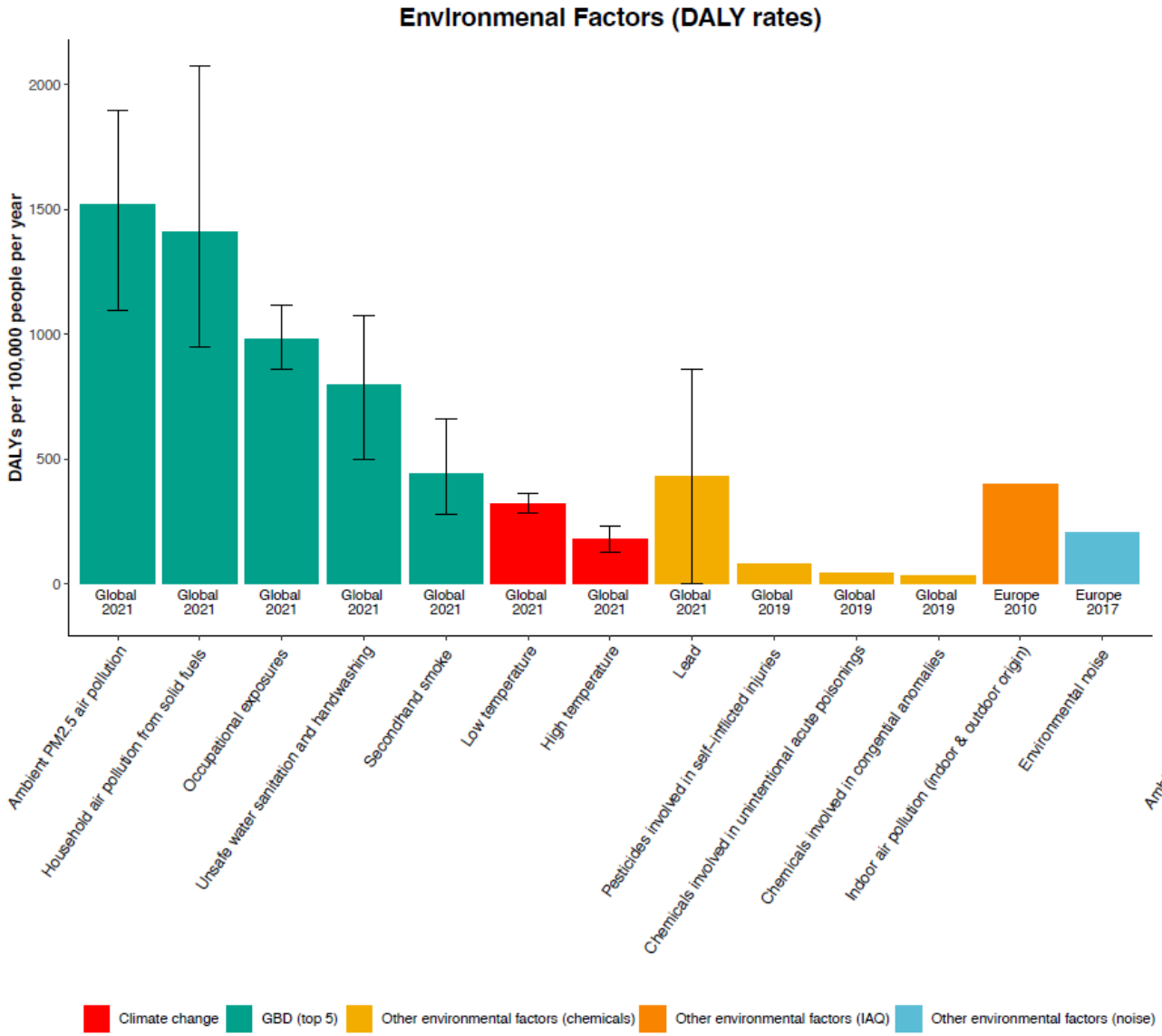
Brauer M et al. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024 May

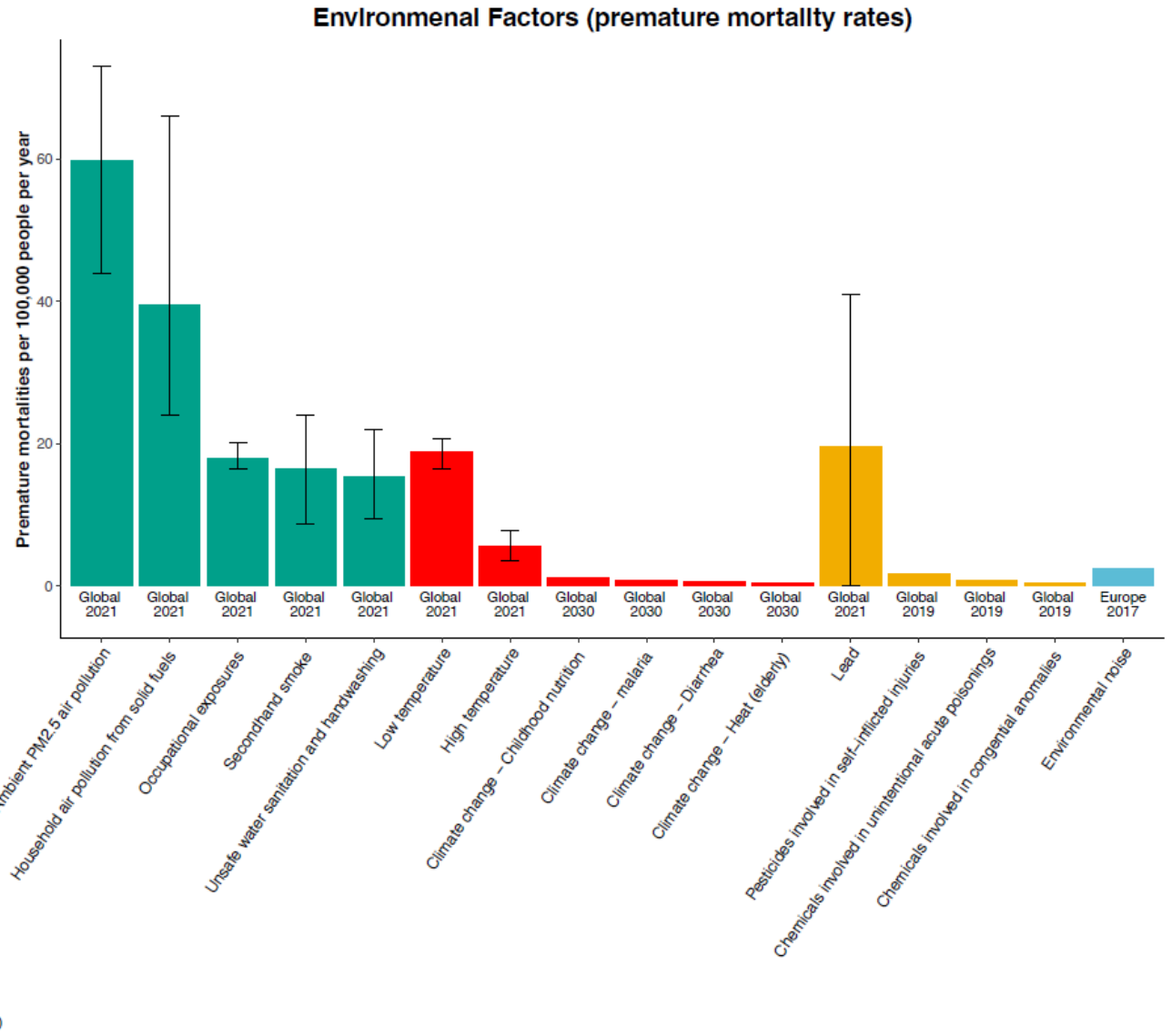
What's missing?

- Solar UV radiation
- Community noise
- Pesticides
- Mercury, Arsenic
- Consumer products exposures (Phthalates, PBDE, PFAS, BPA)
- Drinking water disinfection byproducts
- Nature contact
- Built environment (active-living)

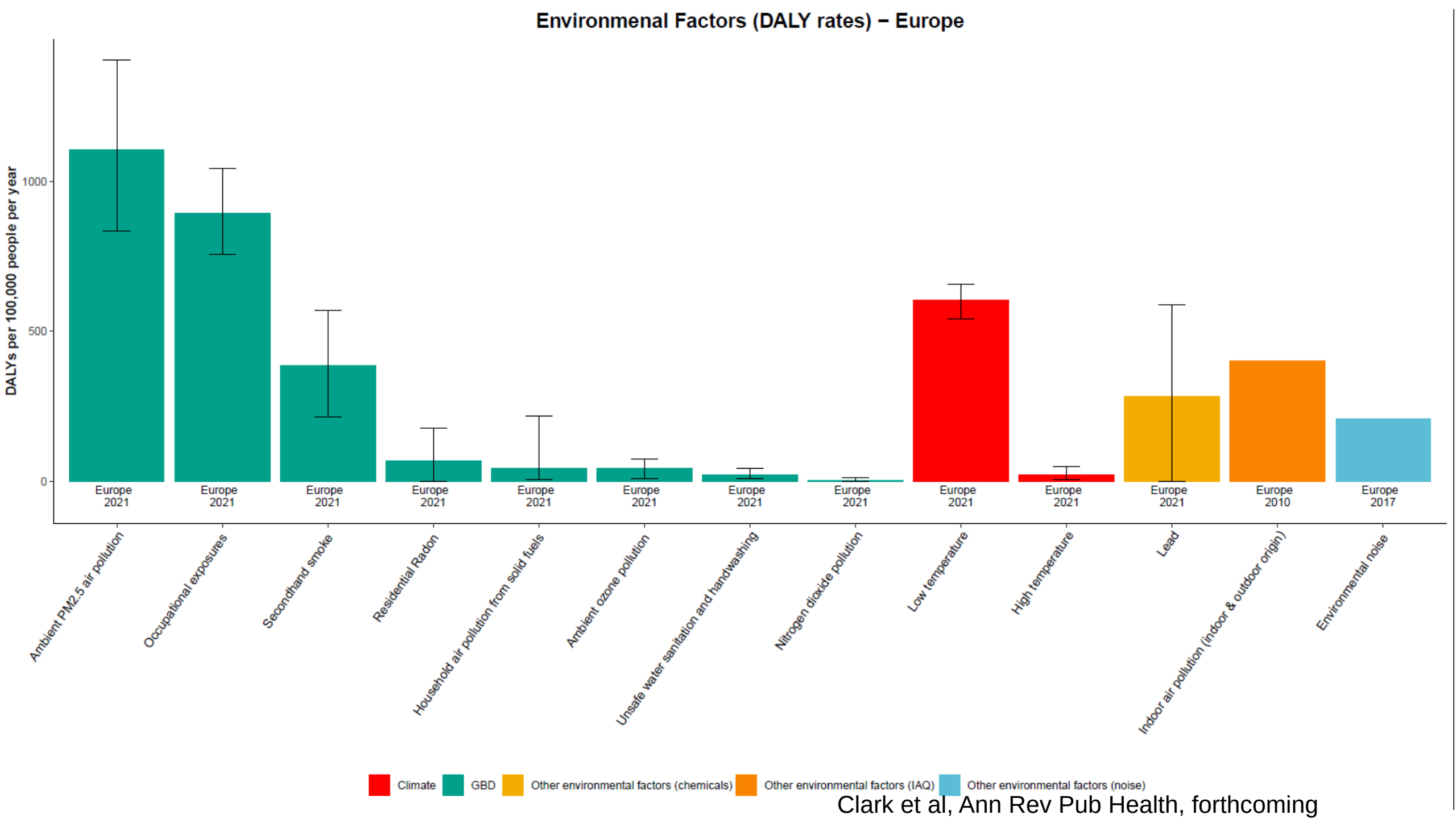


Fuller R et al. Pollution and health: a progress update.Lancet Planet Health. 2022; Shaffer et al. Improving and Expanding Estimates of the Global Burden of Disease Due to Environmental Health Risk Factors. EHP, 2019.





Clark et al, Ann Rev Pub Health, forthcoming

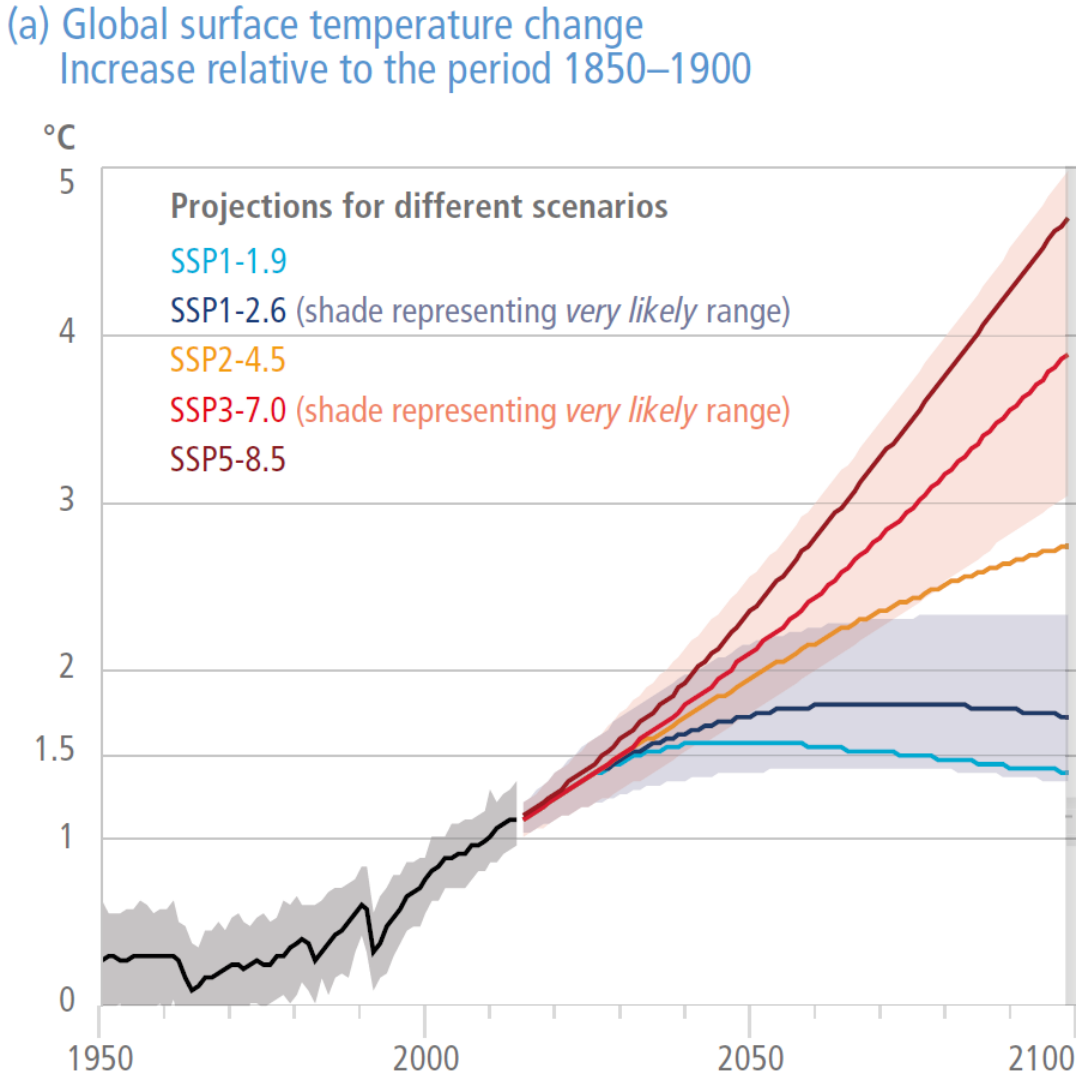


Clark et al, Ann Rev Pub Health, forthcoming

Climate Change

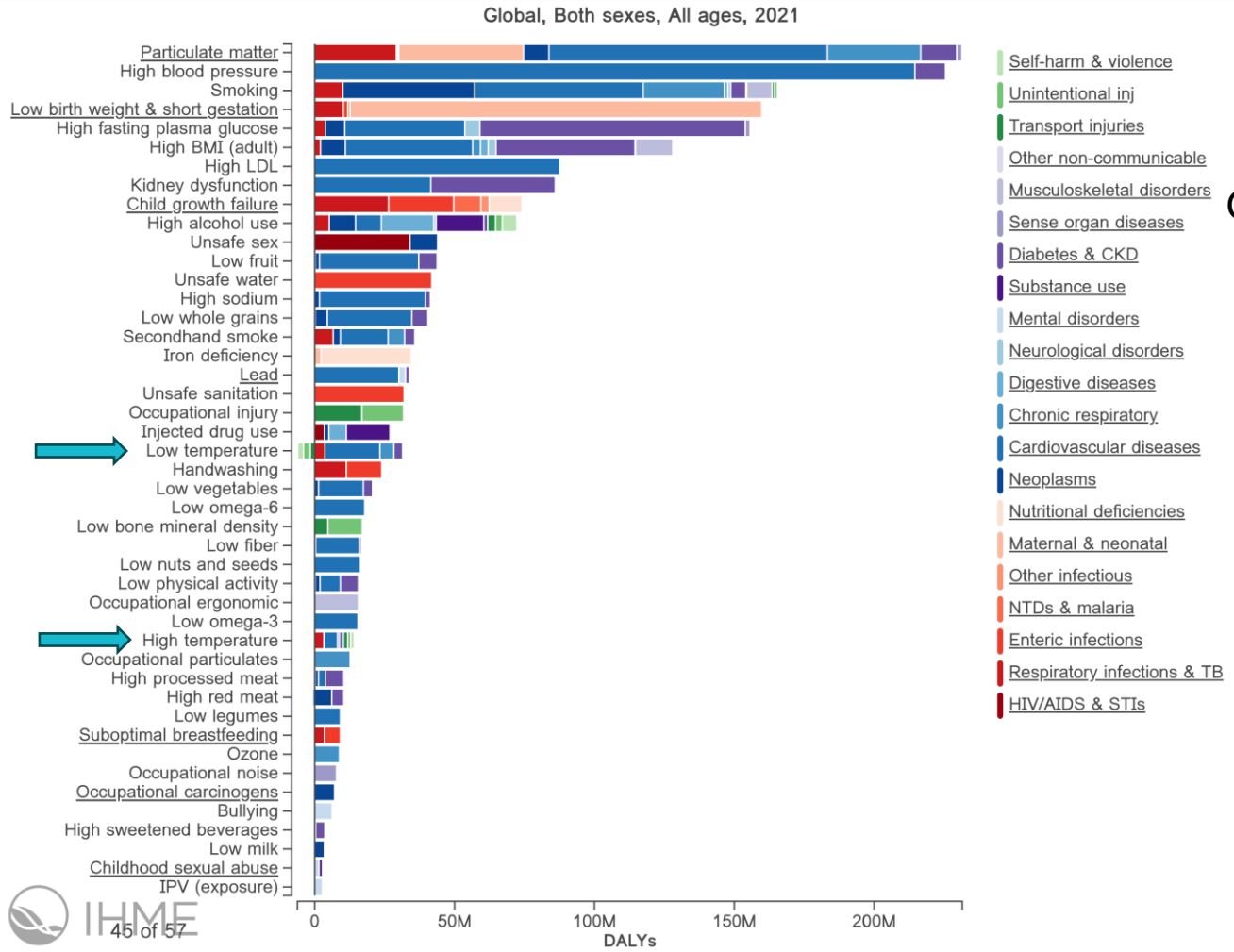
Climate change and health pathways

1. Temperature
2. Air pollution
3. Wildfire smoke
4. Floods (fluvial)
5. Tropical cyclones
6. Malaria and dengue
7. Nutrition/food security
8. Population and migration



Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study

Katrin G Burkart, Michael Brauer, Aleksandr Y Aravkin, William W Godwin, Simon I Hay, Jaiwei He, Vincent C Iannucci, Samantha L Larson, Stephen S Lim, Jiangmei Liu, Christopher J L Murray, Peng Zheng, Maigeng Zhou, Jeffrey D Stanaway



GBD 2021 Burden Attributable to Non-optimal Temperature

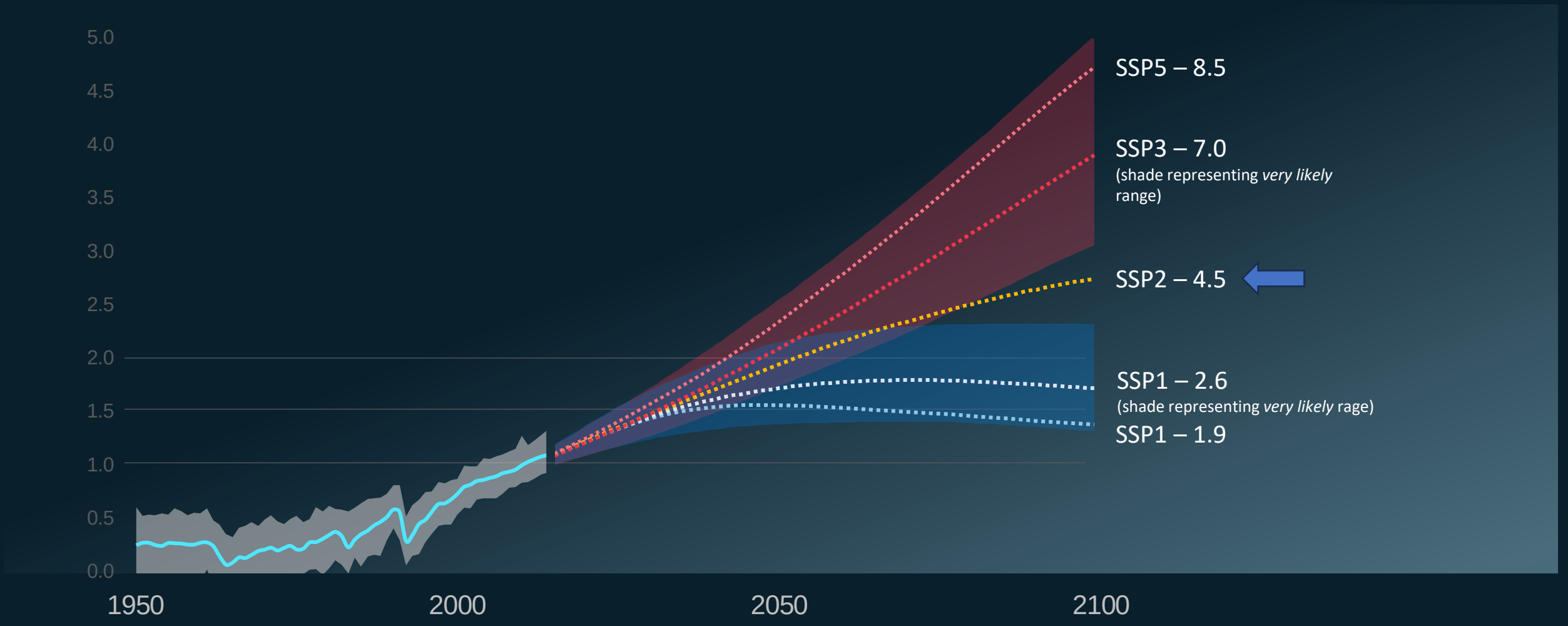
	DALYs (2021)	Deaths (2021)	SEV (ARC 2000-2021)
Non optimal	39.0 M	1.9 M	**0.19**
Low	25.2 M	1.5 M	-0.31
High	14.1 M	0.44M	**0.57**

SEV: Summary Exposure Value. ARC: Annual Rate of Change

High temperature exposure is increasing, not offset by low temperature decrease

Projected global temperature change

Global surface temperature change relative to the period 1850 – 1900 in degrees Celsius



Source: IPCC 2022

Limitations / future considerations

- No risk factors (e.g. BMI) for COVID-19 burden
- Increases in drug use, stress, anxiety, depression during pandemic not fully captured
- COVID-19 accounted for a proportion of deaths/DALYs that would have occurred due to other outcomes
  - Reduced burden available for risk attribution
- Climate change may impact some important risk factor exposures and indirectly impact causes
    - Temperature, air pollution, physical inactivity, dietary (food insecurity), WaSH
    - Malaria, Dengue, Wasting/Stunting, Floods/Storms

Limitations / future considerations

- Missing risk factors for major causes of burden
  - e.g. Mental disorders account for 5·4% of global DALYs, but only 8·0% attributable to risk factors.
  - e.g. musculoskeletal disorders account for 5·6% of global DALYs, but only 20·5% attributable to risk factors.
- Genetic risk factors
- Use of Burden of Proof
  - evaluate potential new risk factors
  - identify R-O pairs (e.g. 1 and 2-star but large burden) for additional research
- Novel aggregations (e.g. Commercial risk factors, diets)

THANK YOU

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Environmental, Occupational and Dietary Risk Factors Team Lead, IHME

Affiliate Professor, Health Metrics Sciences, University of Washington

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