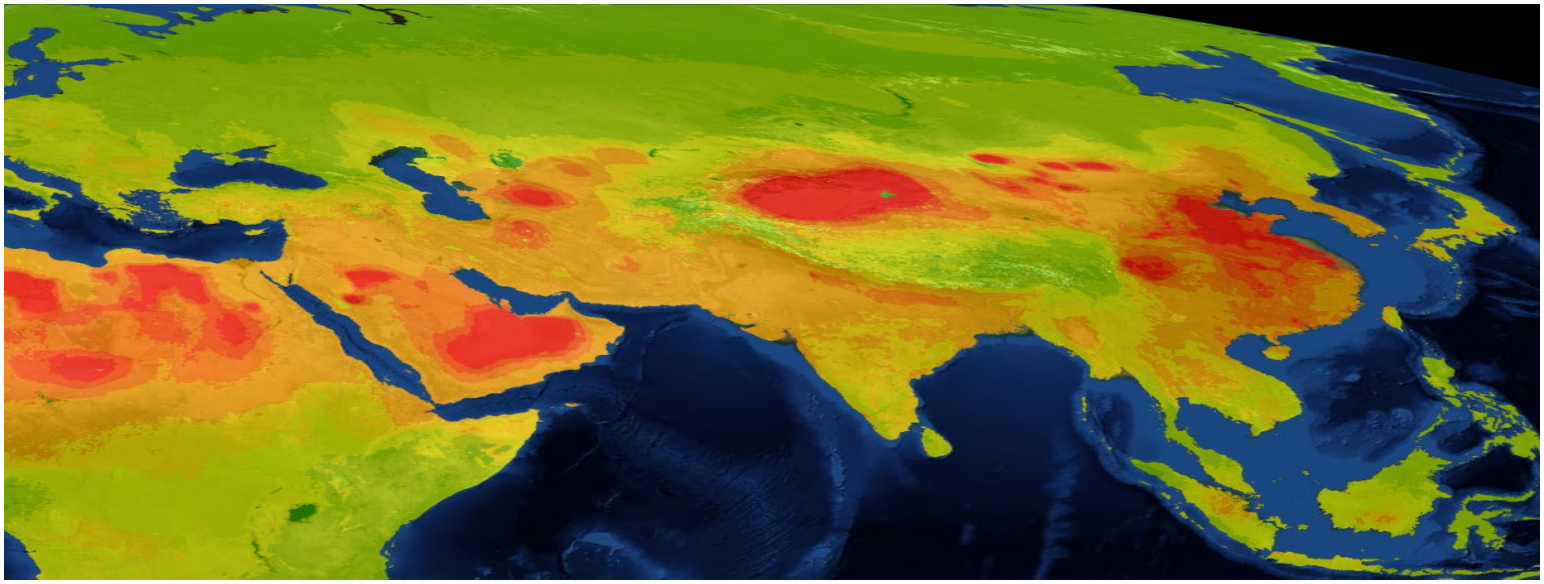
PURE AIR: Assessing Air Pollution Exposure and Human Health Globally



Perry Hystad, Michael Brauer, Salim Yusuf and the PURE team

Population Health Research Institute
HEALTH THROUGH KNOWLEDGE

Oregon State University

THE UNIVERSITY OF BRITISH COLUMBIA

Hamilton Health Sciences

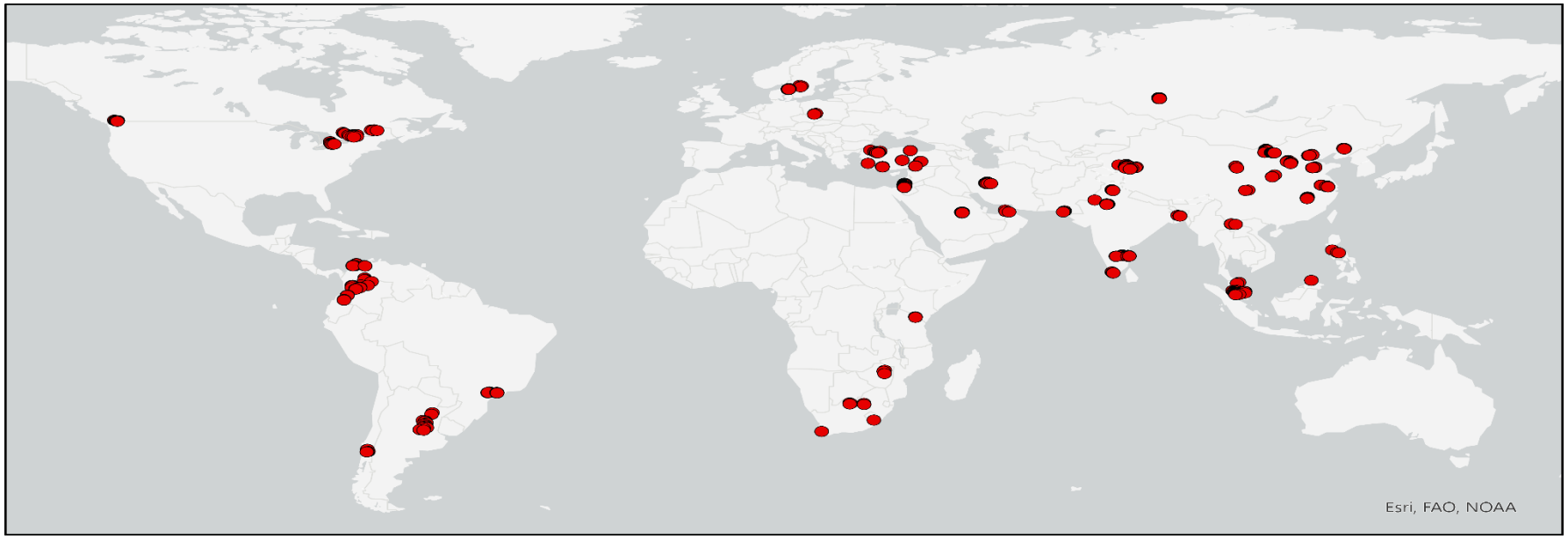
McMaster University
HEALTH SCIENCES

Collaborators!

- Michael Brauer, UBC
- Andrew Larkin, OSU
- Raphael Arku, UBC
- Ying Wang, OSU
- Matt Shupler, UBC
- Courtney Roper, OSU
- John Volckens, CSU
- Aaron van Donkelaar, Dalhousie
- Randal Martin, Dalhousie
- Aaron Birch, UBC
- Kwadwo Boakye, OSU
- Salim Yusuf, PHRI
- Sumathy Rangarajan, PHRI
- The entire PURE team

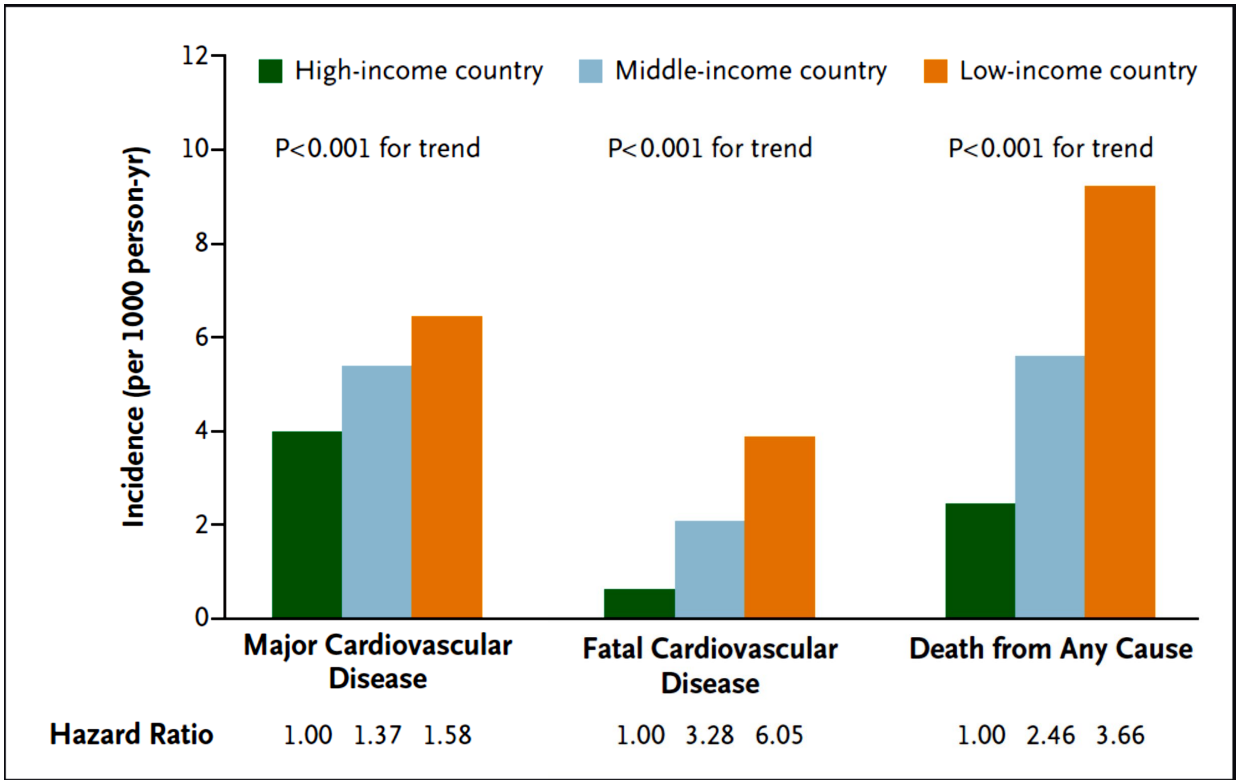
PURE Team, Istanbul 2022

The Prospective Urban and Rural Epidemiological Study (PURE)



- PURE: 160,000 adults (35-70), from 800 urban/rural communities in 27 low-, middle- and high- income countries.
- Started in 2004 (Bangalore, India) with ongoing enrollment and follow-up.
- Comprehensive baseline data collection: individual/household data, medical history, blood collection, lung function.
- Follow-up conducted every 3 years to document health events.

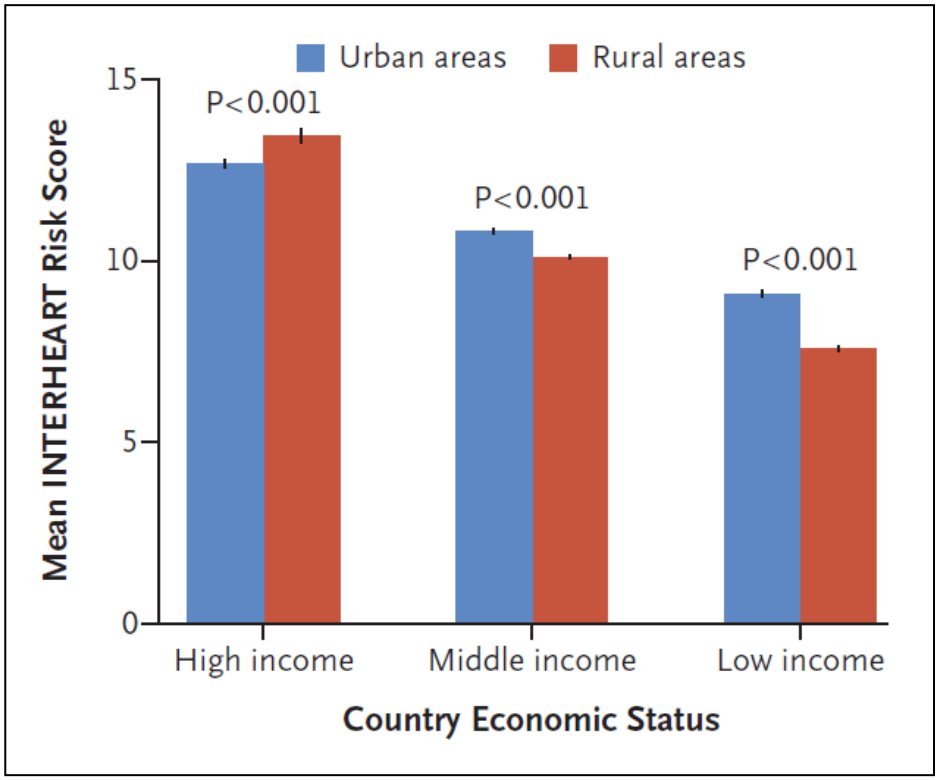
CVD Events at 5 Years



Major CVD = death from CV causes, stroke, MI and HF

Yusuf et al NEJM 2014

Traditional CVD Risk Factors



INTERHEART risk score: age, sex, smoking status, diabetes, high blood pressure, family history of heart disease, waist-to-hip ratio, psychosocial factors, diet, physical activity.

Yusuf et al NEJM 2014

PURE-AIR

PURE-AIR added an ancillary air pollution study to the existing PURE cohort.

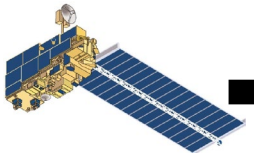
1. Air pollution exposure assessment
2. Repeat lung function measurements
3. Epidemiological analyses

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

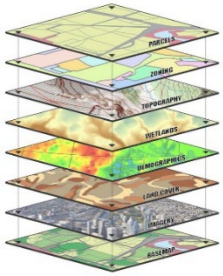
Population Health Research Institute
Health Through Knowledge
PHRI

NIH
National Institutes of Health

Summary of Air Pollution Exposure Assessments in PURE

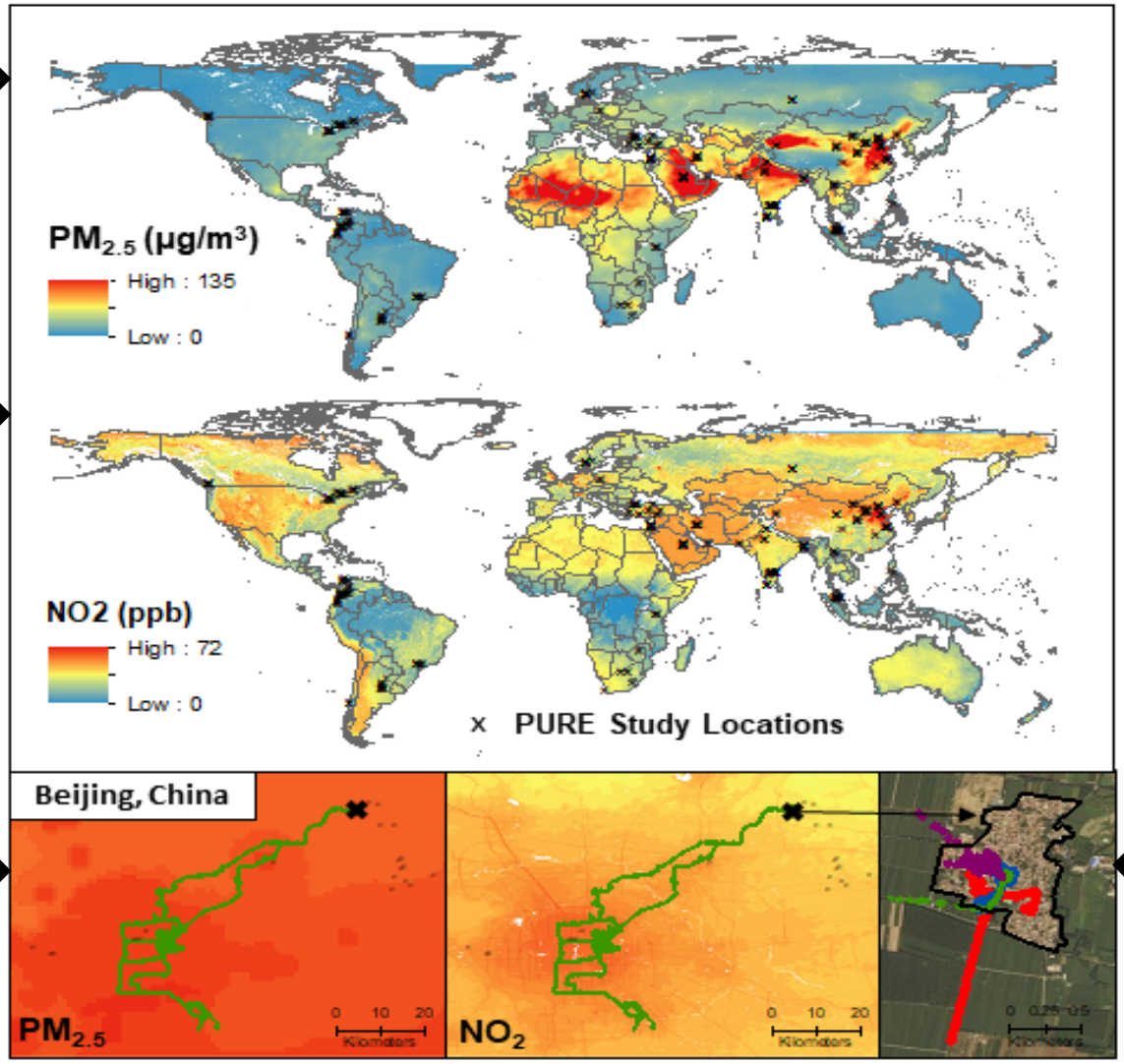


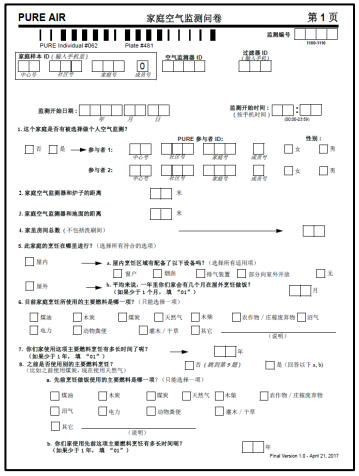
$PM_{2.5}$: 10 km Prediction



NO_2: 100 m Prediction

Air Monitoring & GPS (48 hrs)

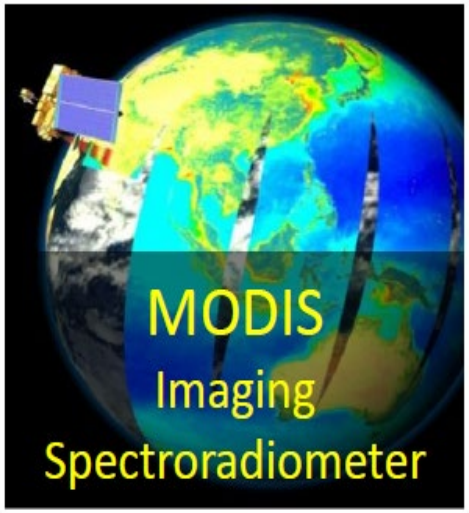


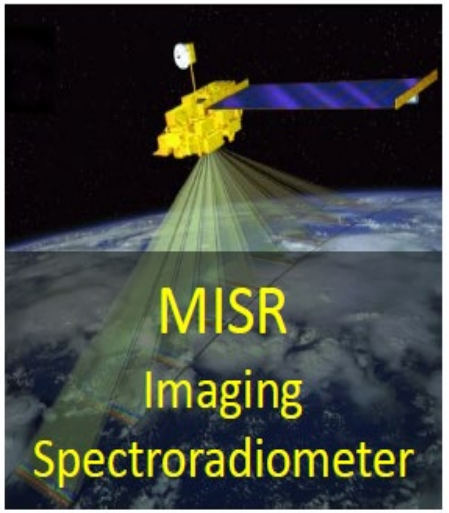


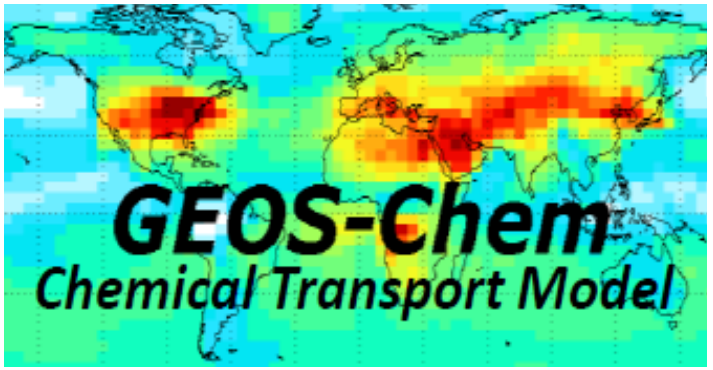
Household & Individual Characteristics

Outdoor $PM_{2.5}$ Exposure Assessment

- Cannot rely on existing air pollution monitoring in many LMICs.
- Use satellite-based estimates of long-term $PM_{2.5}$ air pollution concentrations.
- Global R^2 0.91 with RMSE of 10.7 μg/m^3.

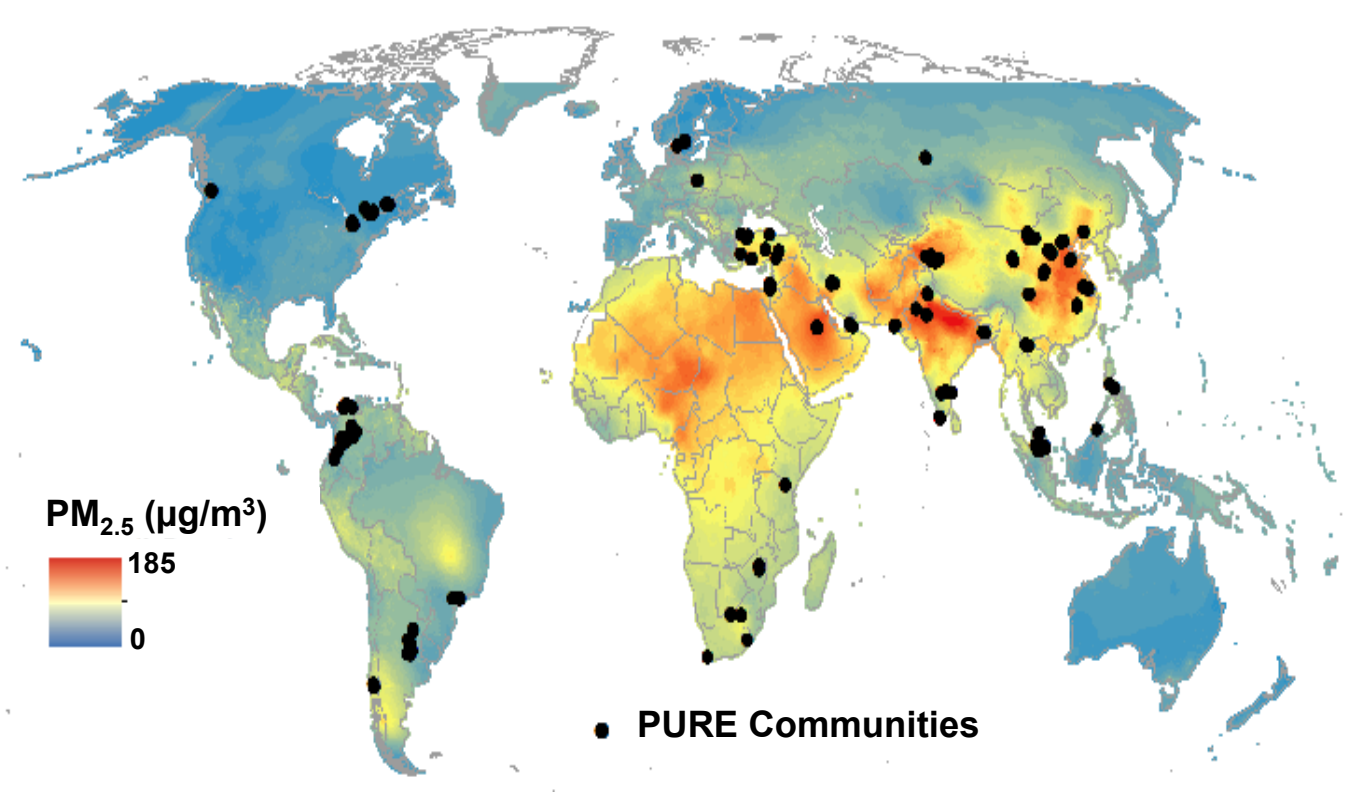


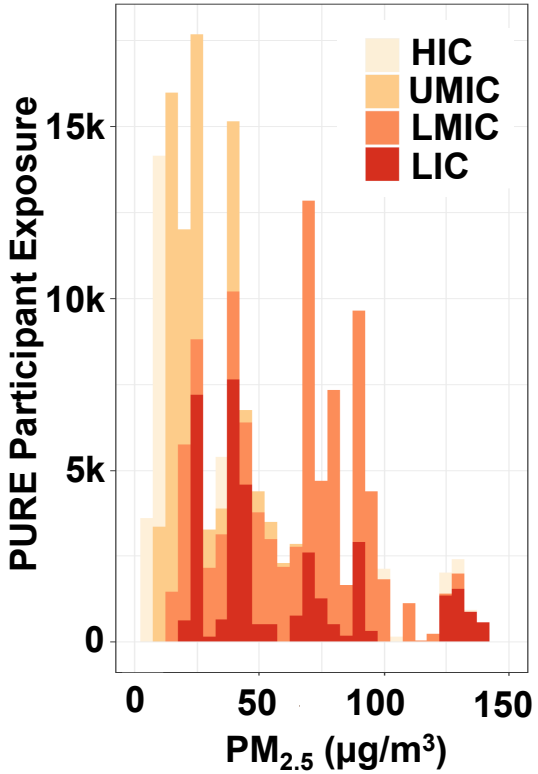




Van Donkelaar et al. EHP 2016
Shaddick et al. EST 2018

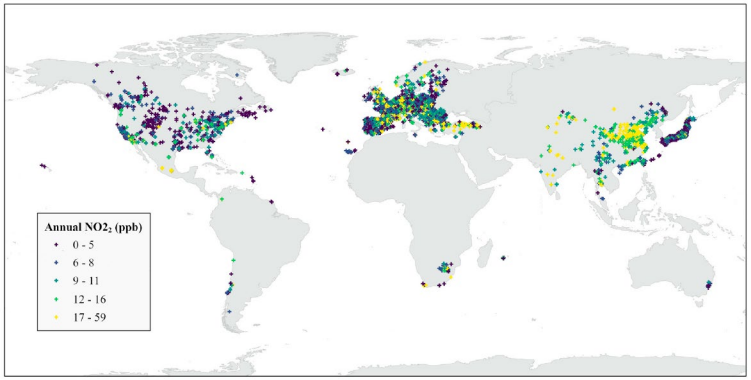
Outdoor $PM_{2.5}$ Exposure Levels From Satellite-Based Measures

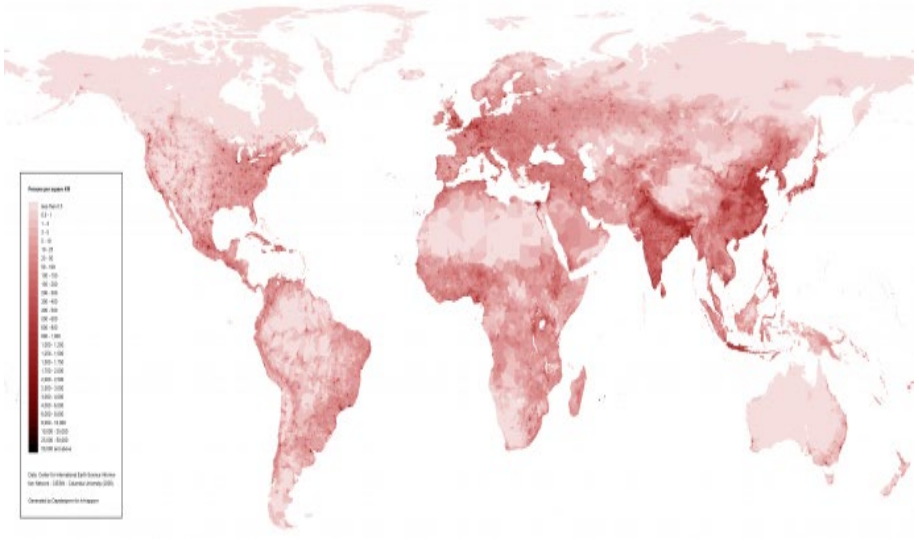


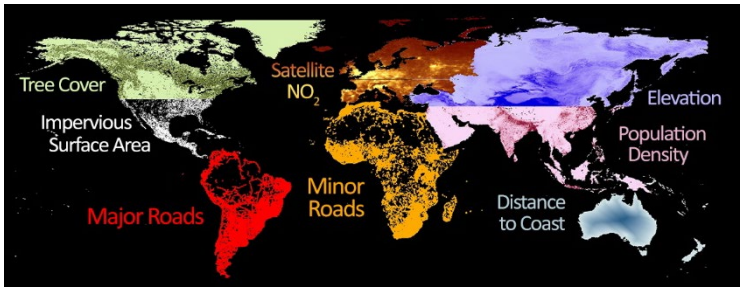


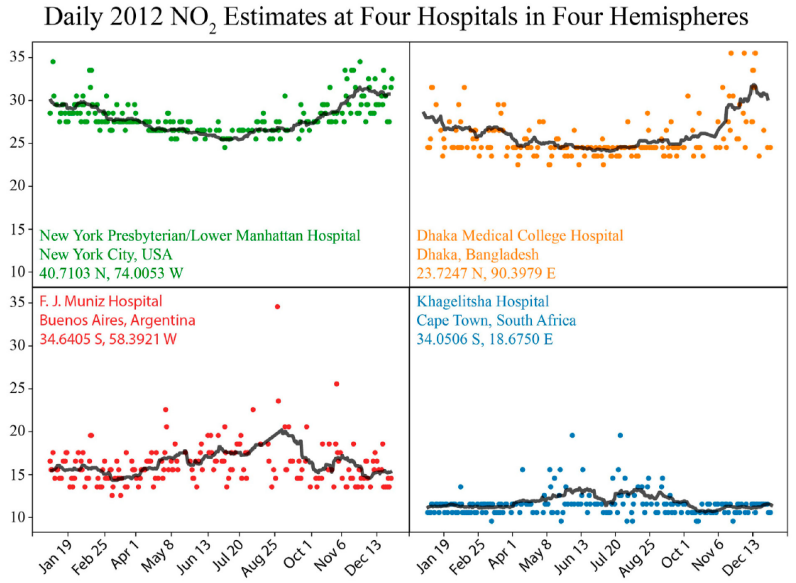
PURE Baseline 3 year mean = 47.5 µg/m³ (std=32.6)

Global Spatial-Temporal LUR NO_2 Model









Larkin et al. Frontiers in Env. Sc. 2023

Household & Personal Air Monitoring

- Household (n=2,500) and personal (n=1,400) samples collected in rural PURE communities with >10% biomass use for cooking.
- UPAS monitor collected filter-based air samples.
- Measured $PM_{2.5}$ and Black Carbon concentrations.
- Sub-set of individuals (n=600) wore wristband samplers to measure 1,500 organic chemicals and PAHs.

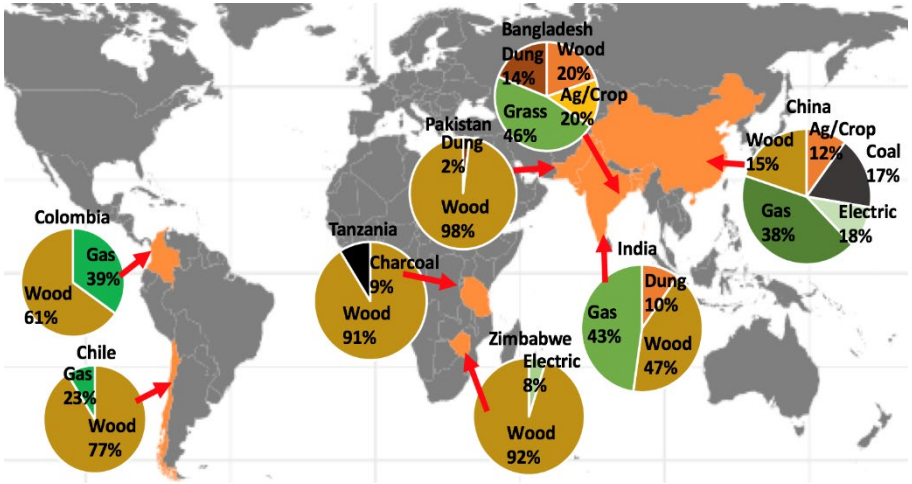
Standardized Equipment, Protocols, Training

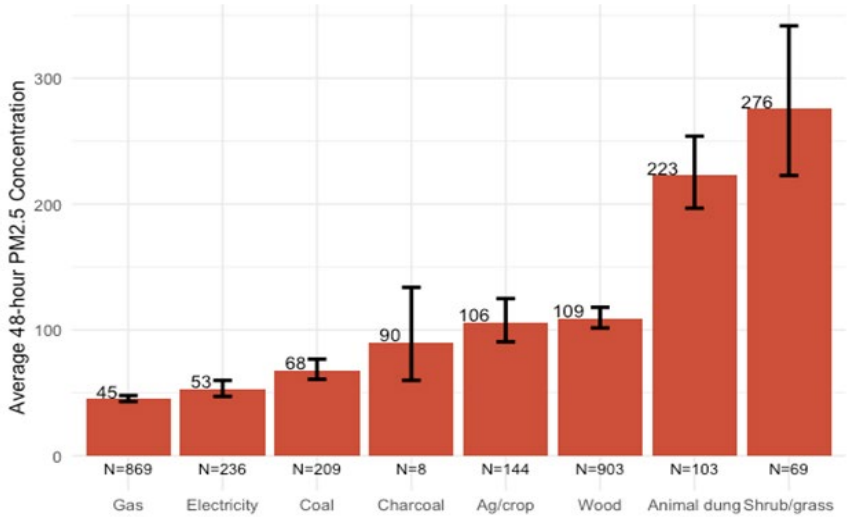
Home Monitoring

Personal Monitoring

Monitoring Results

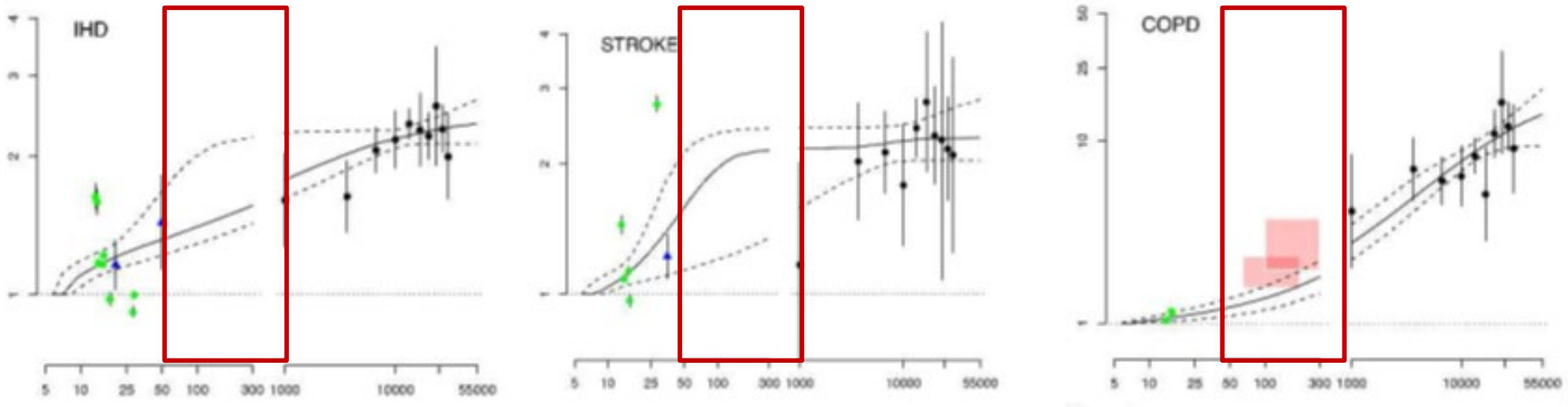
- 2,541 households and 1,250 individuals in 120 communities.
- Strong gradient in $PM_{2.5}$ by cooking fuels.
- Average $PM_{2.5}$ measurements for all fuel types above the WHO Target-1 (35 $\mu g/m^3$).
- Minor differences between average male and female $PM_{2.5}$ exposures (varied by country).
- PURE-AIR measures double the available HAP $PM_{2.5}$ samples in the WHO database.





Shupler et al. LPH 2020

PURE-AIR Epidemiology



1. Few studies conducted in developing countries and at moderate-to-high $PM_{2.5}$ levels.
2. Important population differences and co-exposures.
3. No study of household air pollution and CVD incidence.

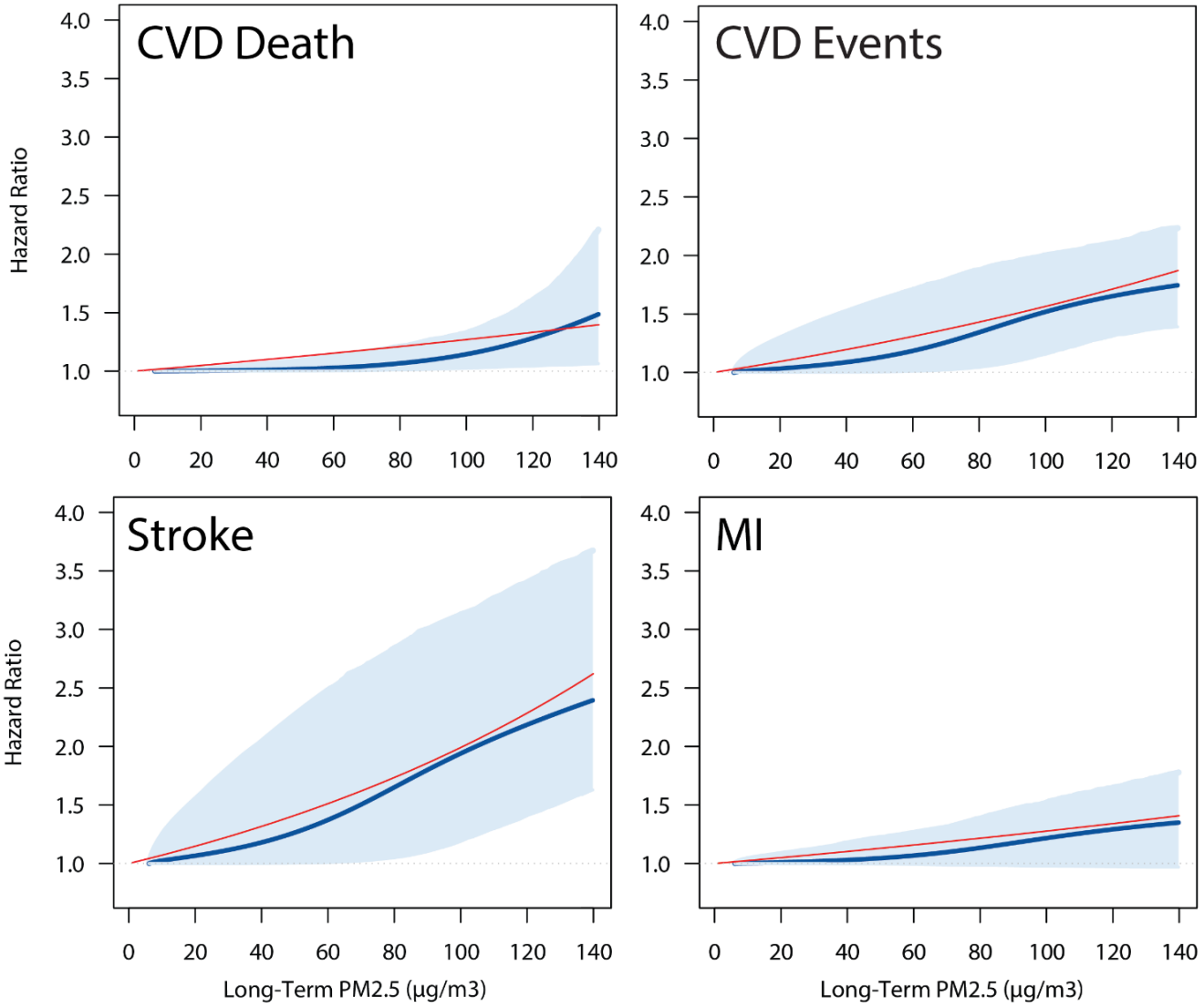
Outdoor $PM_{2.5}$ (per 10 µg/m^3 increase)

	Events	Base Model	Adjusted Model	+Geographic Variables
CVD Events[a]	9 152	1·09 (1·07-1·11)	1·05 (1·03-1·07)	1·08 (1·01-1·16)
MI	4 083	1·07 (1·05-1·10)	1·03 (1·00-1·06)	1·11 (1·02-1·21)
Stroke	4 139	1·13 (1·10-1·15)	1·07 (1·05-1·10)	1·11 (1·00-1·22)
CVD Death	3 219	1·07 (1·04-1·10)	1·03 (1·00-1·06)	1·12 (1·02-1·23)
Death[b]	9 996	1·01 (0·99-1·03)	0·98 (0·96-0·99)	1·08 (1·01-1·15)

Base: Age, sex, baseline year, community random effect.
Adjusted: Model 1 plus smoking status, physical activity, PURE diet score, waist to hip ratio, INTERHEART risk score, use of solid fuels for cooking, education level, household wealth index, occupational class, baseline chronic condition, use of CVD medication, and hypertension status, urban/rural status, baseline country GDP per person, community lights at night satellite data (indicator of local economic activity), and a national or regional healthcare access & quality index.
Fixed effects: Model 3 with a fixed effect for each center urban/rural area.
[a] Death from cardiovascular causes and non-fatal myocardial infarction, stroke, and heart failure· Each sub-category includes fatal and non-fatal events. [b] All deaths excluding injuries.

Hystad et al. LPH 2020

Concentration-Response

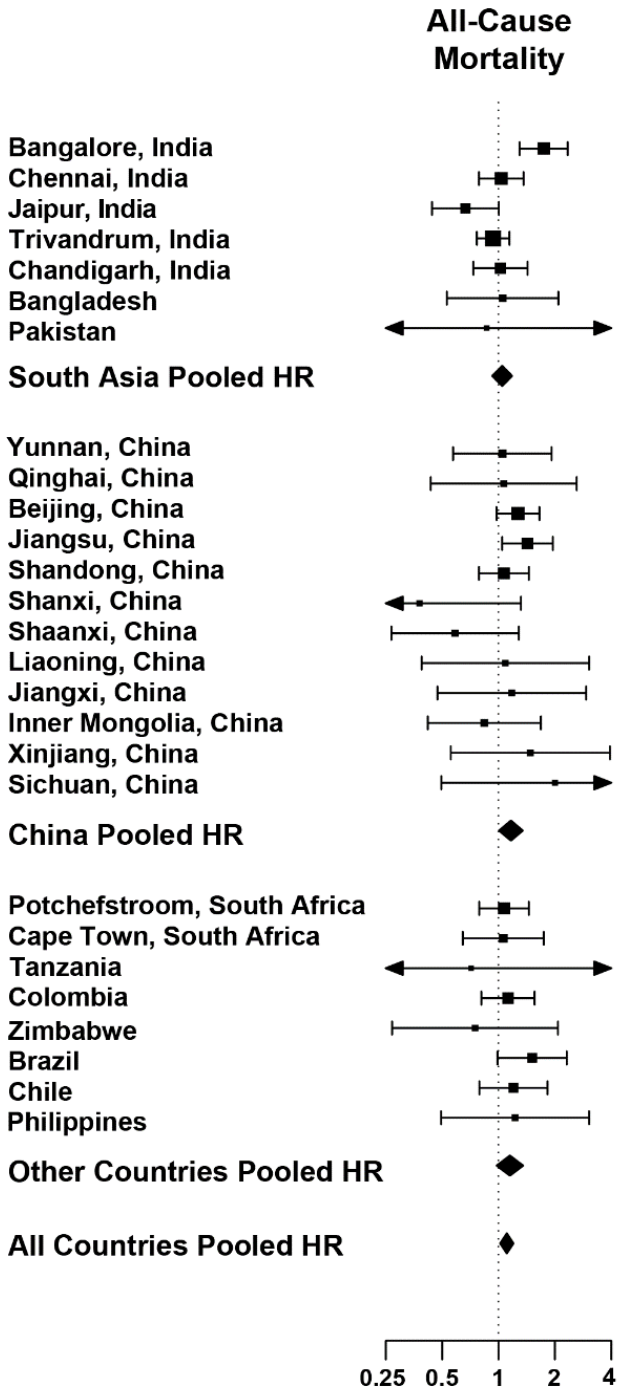


Hystad et al. LPH 2020

Cooking with Solid Fuels Versus Clean

	n	Events	Adjusted Model	+ SES Factors
CVD Events[a]	91,350	5 472	1.14 (1.05, 1.23)	1.08 (0.99, 1.17)
MI	91,350	2 363	1.12 (1.00, 1.26)	1.07 (0.94, 1.22)
Stroke	91,350	2 685	1.16 (1.03, 1.30)	1.12 (0.99, 1.17)
CVD Death	91,350	2 104	1.18 (1.04, 1.34)	1.04 (0.91, 1.19)
Mortality[b]	91,350	6 595	1.24 (1.16, 1.34)	1.12 (1.04, 1.21)

Model 1: Age, sex, baseline year, strata for center and urban/rural status, INTERHEART risk score, smoking, physical activity, alcohol use, alternative healthy eating index, BMI, baseline chronic condition, baseline CVD medication use, baseline hypertensive status, outdoor PM25.
Model 2: Model 1 + education, percentage income spent on food, and strata for household wealth index tertile.
[a] Death from cardiovascular causes and non-fatal myocardial infarction, stroke, and heart failure· Each sub-category includes fatal and non-fatal events.
[b] All deaths excluding injuries



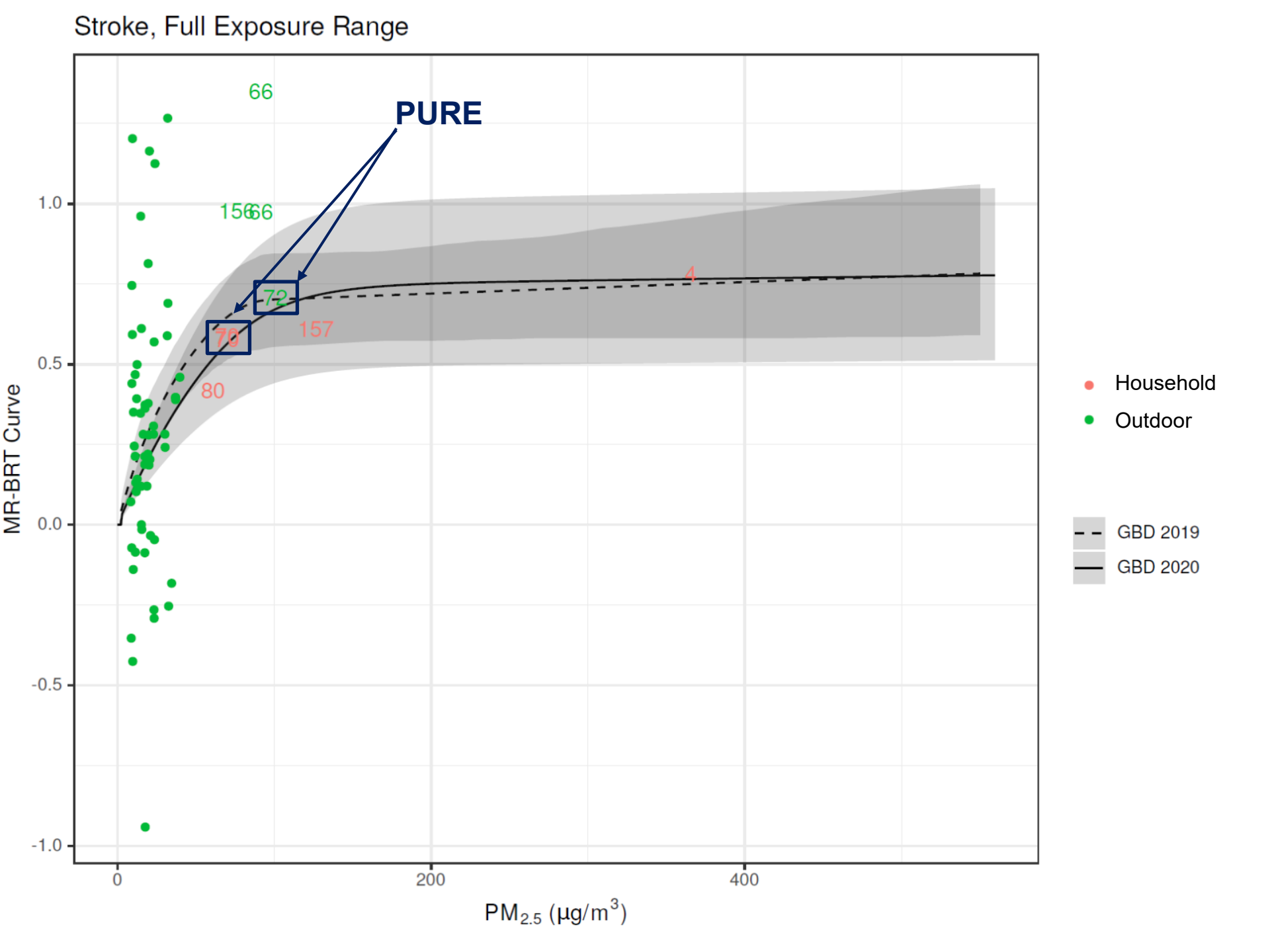
Hystad et al. EHP 2019

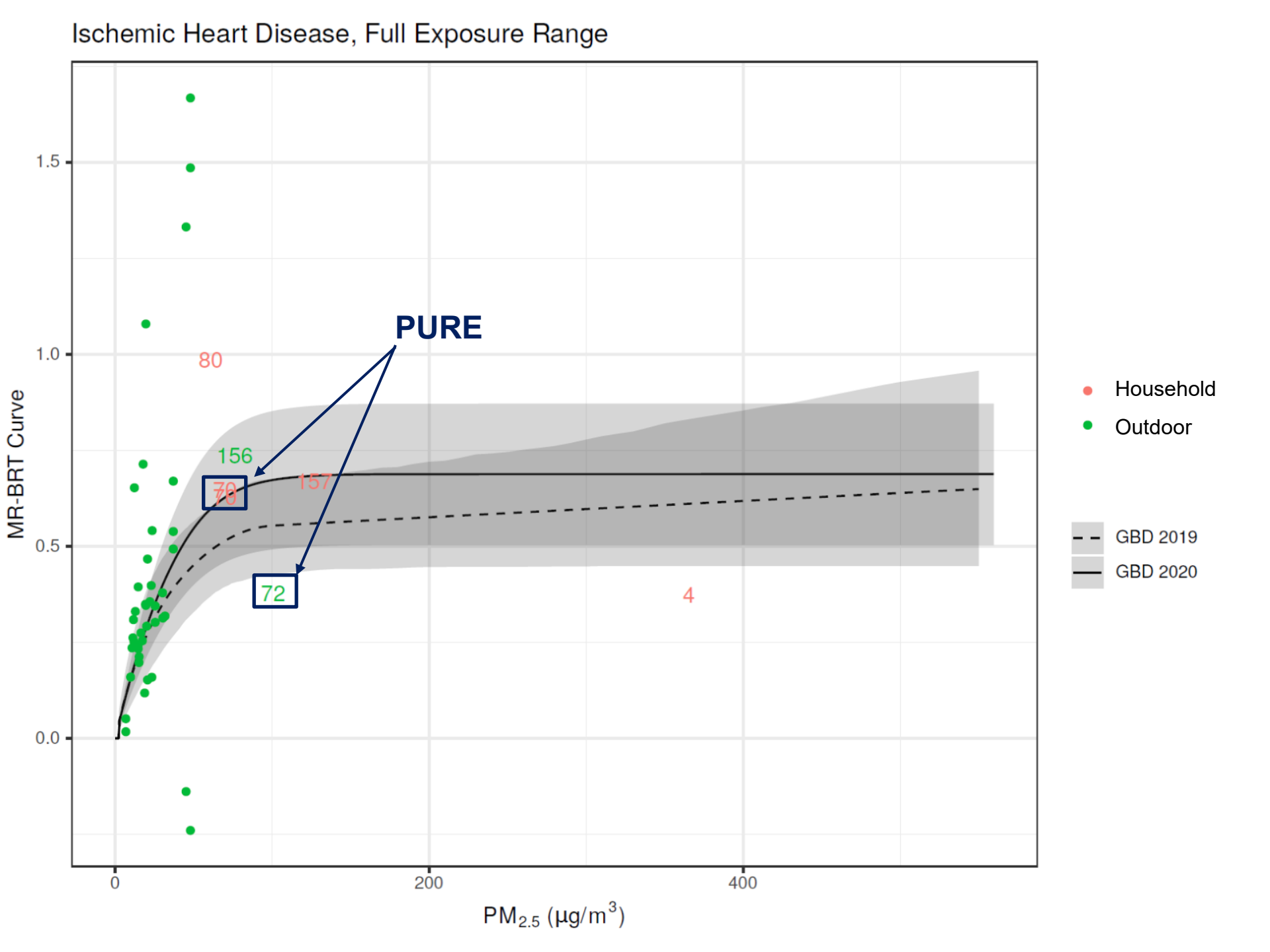
Households Switching from Solid to Clean Fuels During Follow-Up

	n	Respiratory Events HR (95% CI)	Mortality HR (95% CI)
Persistent solid fuels	4520	ref	ref
Switched to clean fuels	3901	0.76 (0.57, 1.00)	0.85 (0.62, 1.17)

Model 1: Age, sex, baseline year, strata for center and urban/rural status, INTERHEART risk score, smoking, physical activity, alcohol use, alternative healthy eating index, BMI, baseline chronic condition, baseline CVD medication use, baseline hypertensive status, outdoor PM25.
Model 2: Model 1 + education, percentage income spent on food, and strata for household wealth index tertile.
[a] Death from cardiovascular causes and non-fatal myocardial infarction, stroke, and heart failure· Each sub-category includes fatal and non-fatal events.
[b] All deaths excluding injuries

Wang et al. EHP 2023


Stroke, Full Exposure Range
PURE
66
156
66
72
157
79
80
4
1.0
0.5
0.0
-0.5
-1.0
MR-BRT Curve
0
200
400
PM2.5 (µg/m3)
Household
Outdoor
GBD 2019
GBD 2020


Ischemic Heart Disease, Full Exposure Range
MR-BRT Curve
1.5
1.0
0.5
0.0
0
200
400
PM2.5 (µg/m3)
PURE
80
156
70
70
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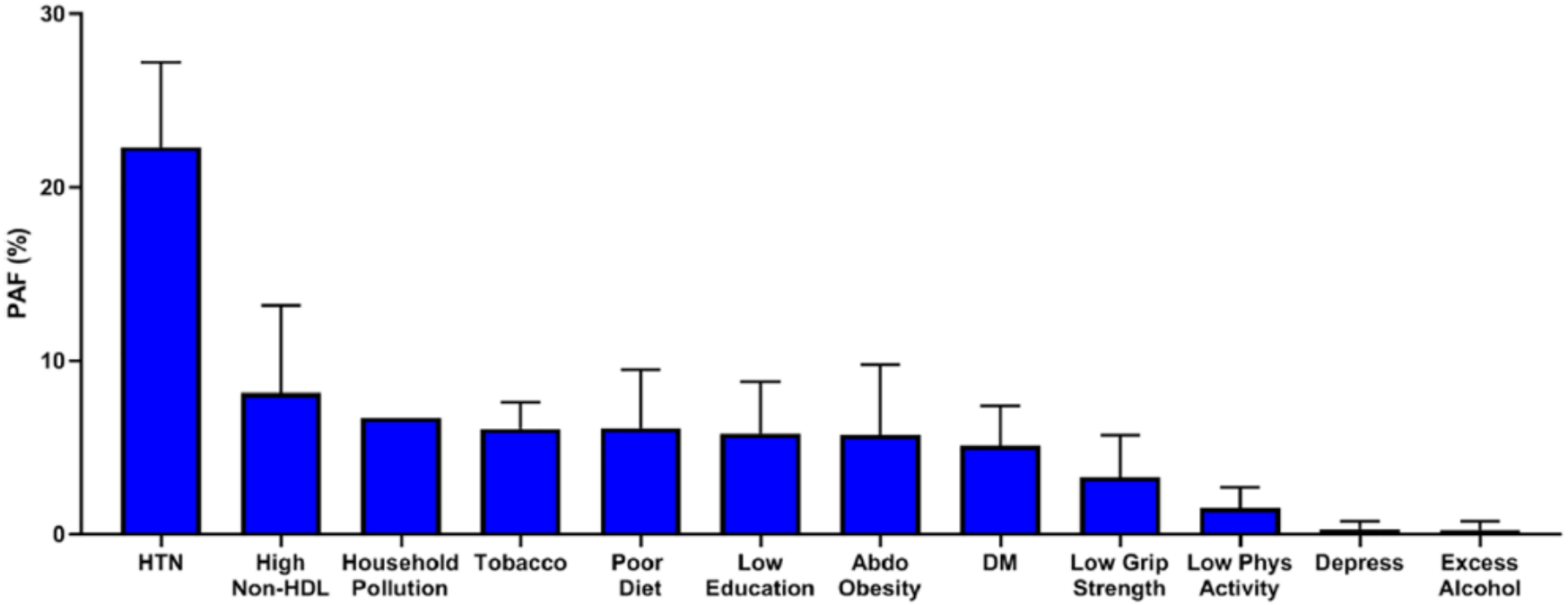
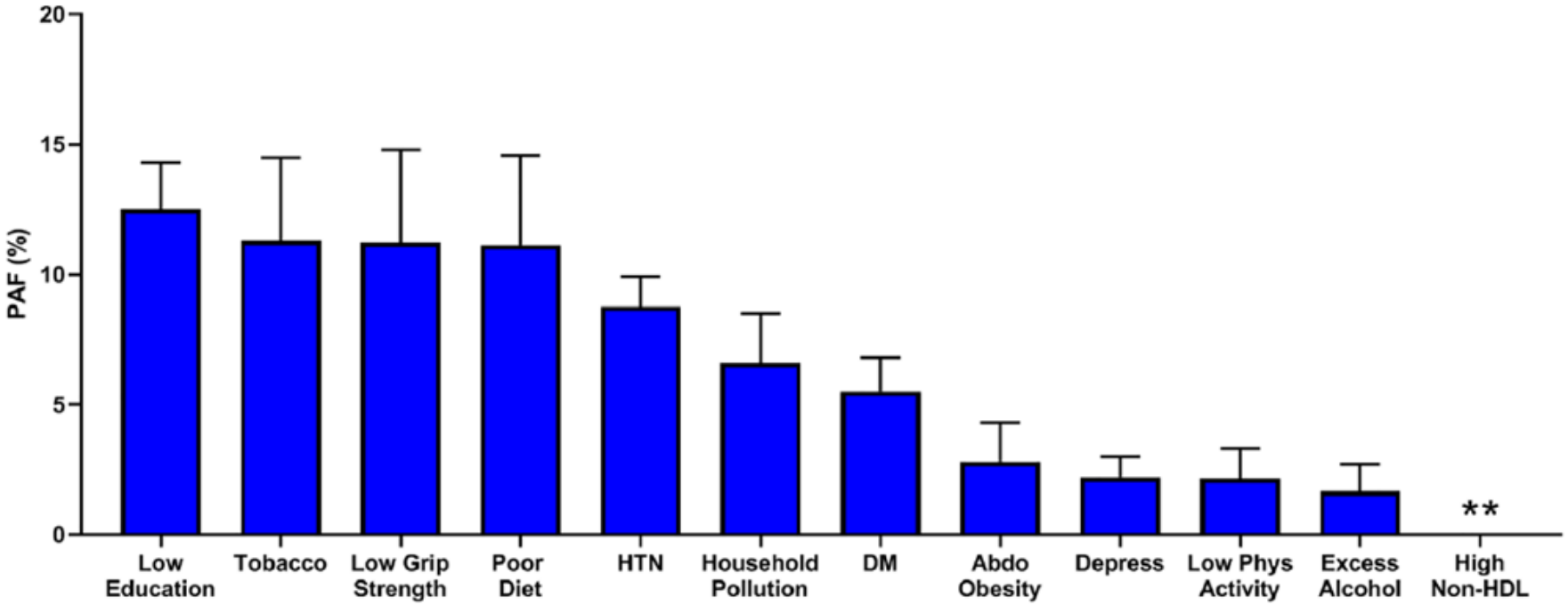
72
4
Household
Outdoor
GBD 2019
GBD 2020

PURE Integrated Analysis of Modifiable Risk Factors for CVD



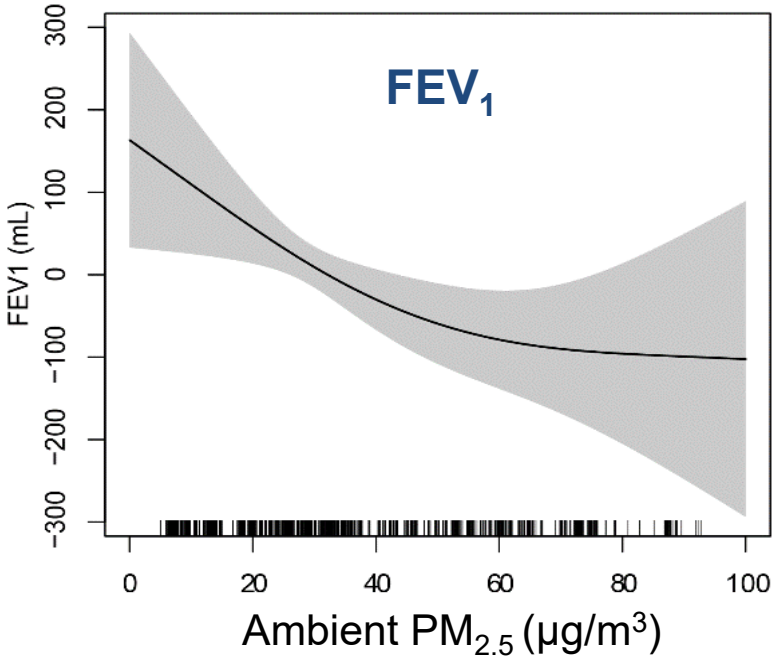
Yusuf et al. Lancet 2020

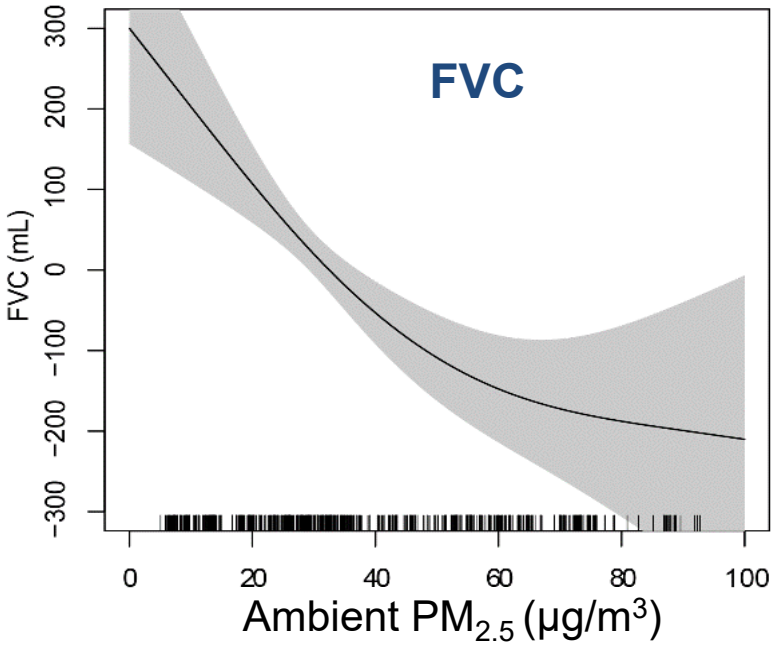
PURE Integrated Analysis of Modifiable Risk Factors for Mortality



Yusuf et al. Lancet 2020

Lung Function





	FEV1 ml β (95%CI)	FVC ml β (95%CI)	FEV1/FVC % β (95%CI)
Clean cooking fuels	ref	ref	ref
Solid cooking fuels	-17.5 (-32.7, -2.3)	-14.4 (-32.0, 3.2)	-0.1 (-0.4, 0.2)

Adjusted for: Age, sex, baseline year, strata for center and urban/rural status, INTERHEART risk score, smoking, physical activity, alcohol use, alternative healthy eating index, BMI, baseline chronic condition, baseline CVD medication use, baseline hypertensive status, outdoor PM25, education, percentage income spent on food, and strata for household wealth index tertile.

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Measured $PM_{2.5}$ and Respiratory Symptoms

	N[a]	Household $PM_{2.5}$ (OR, 95%CI)	Personal $PM_{2.5}$ (OR, 95%CI)
Individual Symptoms			
Breathlessness	135	1.11 (0.98, 1.25)	1.08 (0.91, 1.28)
Cough at least 2 weeks	94	1.22 (1.06, 1.39)	1.06 (0.87, 1.30)
Sputum	98	1.26 (1.10, 1.44)	1.19 (1.00, 1.41)
Wheezing/chest whistling	48	1.25 (1.07, 1.46)	1.23 (1.00, 1.50)
Respiratory function impairment	103	1.11 (0.94, 1.30)	1.20 (1.01, 1.43)
Number of Symptoms[d]			
2 Symptoms	48	1.22 (1.03, 1.44)	1.12 (0.90, 1.39)
≥3 Symptoms	57	1.25 (1.06, 1.48)	1.20 (0.98, 1.48)

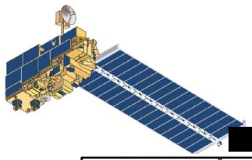
*Scaled per IQR (119.1 ug/m^3) increase in household $PM_{2.5}$ and IQR (91.5 ug/m^3) increase in personal $PM_{2.5}$

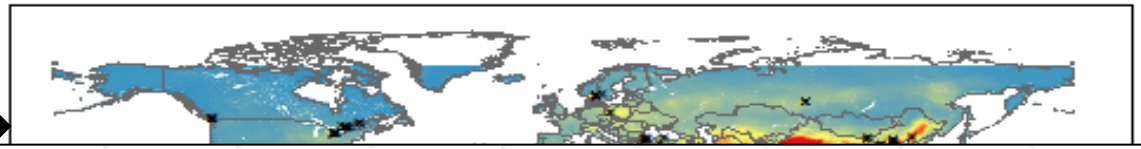
[a] Number of individuals reporting symptoms. Total sample size is 870.

Adjusted model: Age, sex, current smoker, second-hand smoke exposure, education, household wealth index, ambient annual $PM_{2.5}$

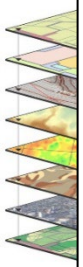
Wang et al. Env. Research 2022

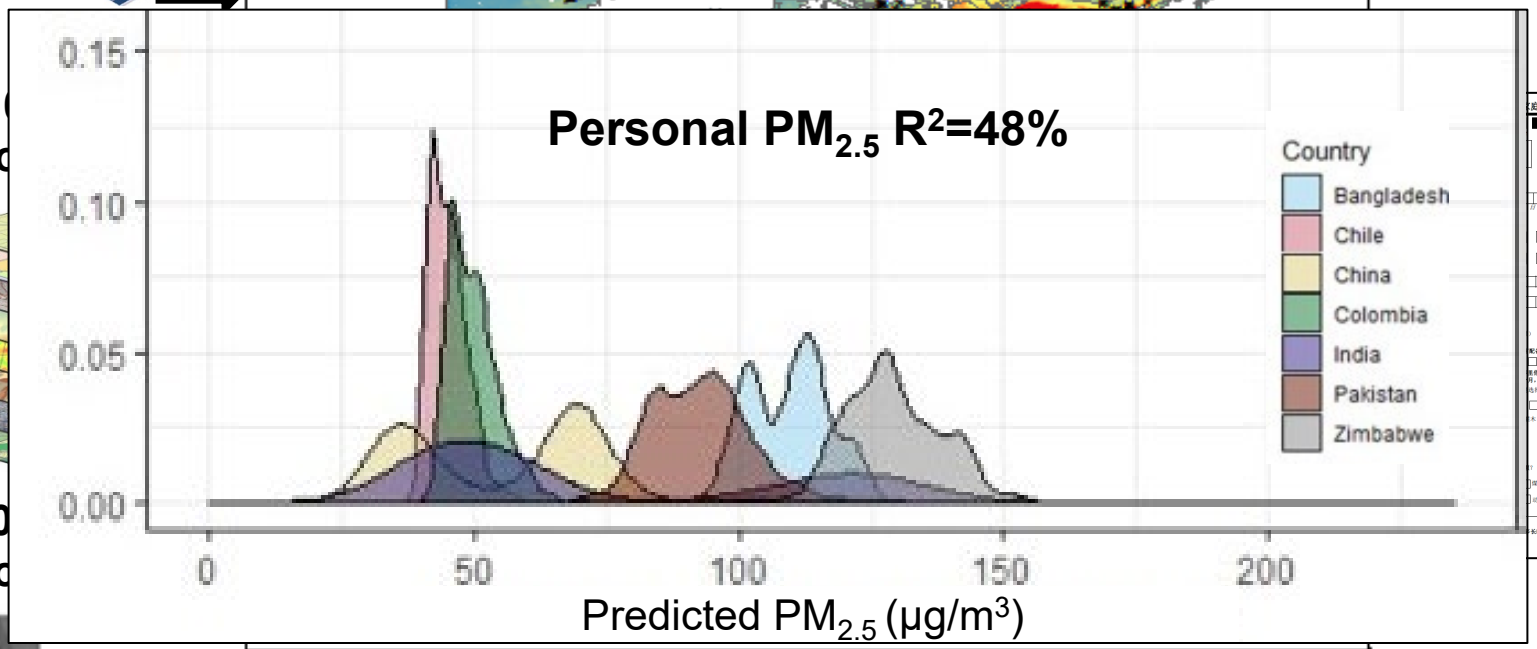
Total Air Pollution Exposure

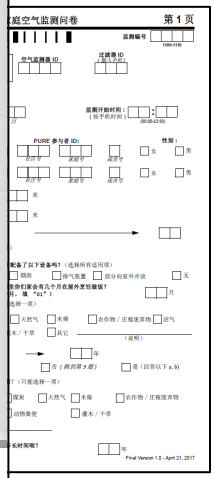




$PM_{2.5}$: 1(
Predictio

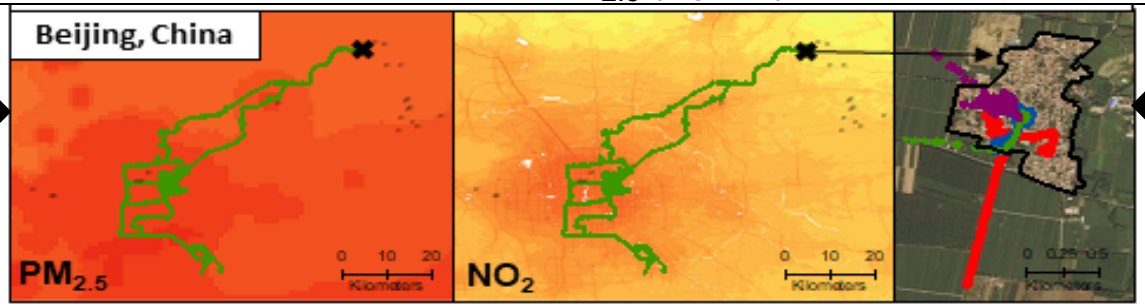






NO_2: 100
Predictio

Air Monitoring & GPS (48 hrs)



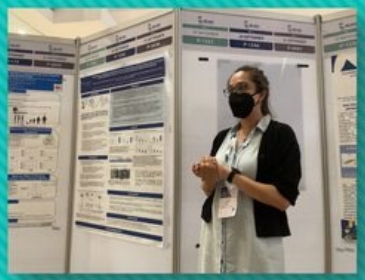
Household & Individual Characteristics

Wang et al. Sci. Total Env. 2021; Shupler et al. Env. Int. 2022

Research Collaboration and Logistics

- PURE-Air feasible due to the long-standing collaborations and buy-in from local PURE investigators.
- Local field staff (no experience with air sampling) were able to effectively collect air pollution measures.
- Study built local capacity for air pollution research - many new local and country projects and analyses.
- Don’t underestimate logistic challenges – survey translation, shipping, local IRB, sending money, power….
- Data overload!

Join us in June!!!



Register Now!

Visit https://bit.ly/43akASW to register.

ISEE North American Chapter Conference
June 19-21
Corvallis, Oregon

Thank You!

Perry.Hystad@oregonstate.edu