

Air pollution and its reproductive effects on human beings in China

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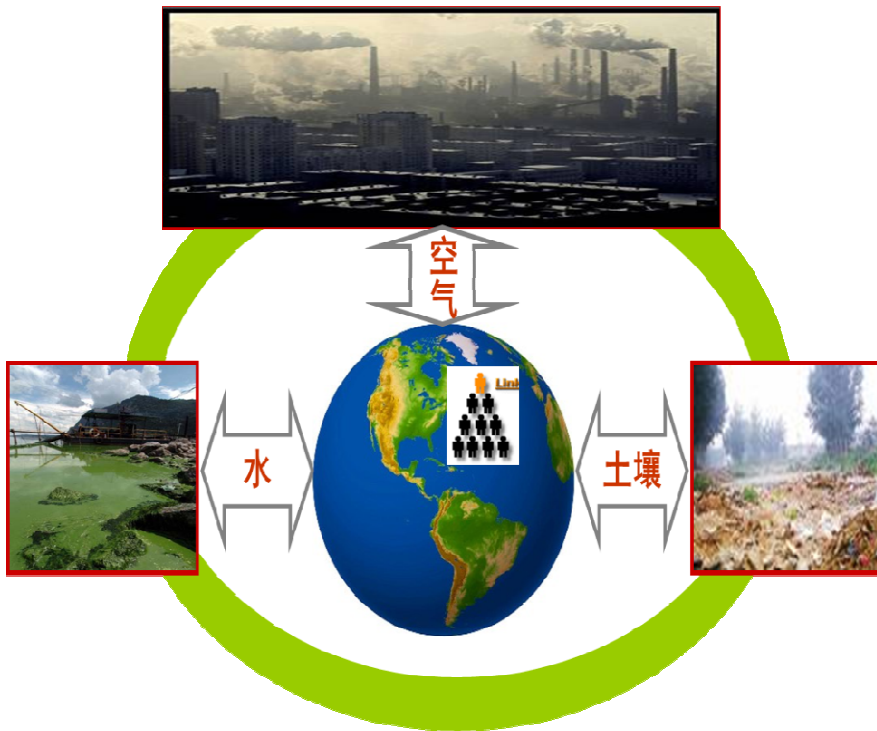
Outline

- **Background**
- **Ambient air pollution and reproductive health in China – epidemiologic evidence**
- **Future research needs**

“Pollution in China” – by LU Guang



In terms of health, air pollution is most significant among various environmental risks in China

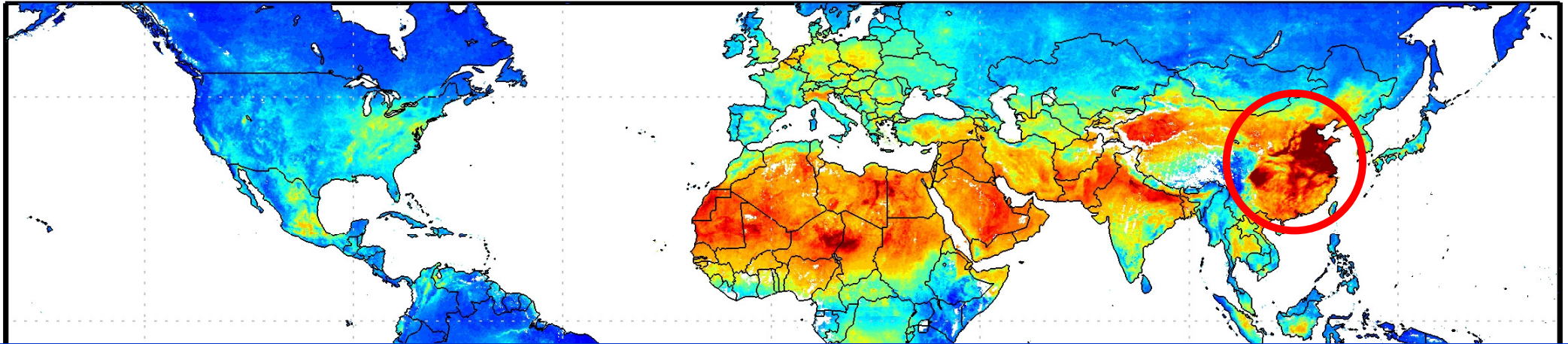


Cost of environmental pollution in China in 2003

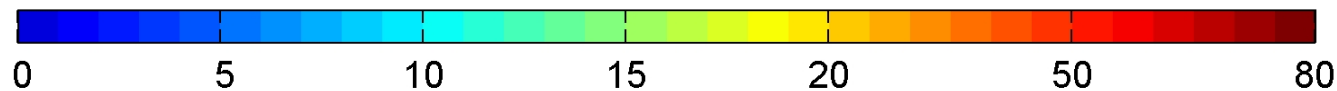
	Air pollution	Water pollution
Disease burden	400,000 premature deaths	52,000 cancer deaths
Health economic loss	519,9 Billion □	9.5 Billion □
Other economic loss	36,7 Billion □	158,0 Billion □

Source: World Bank, *Cost of Pollution in China*

Satellite Global PM_{2.5} concentrations



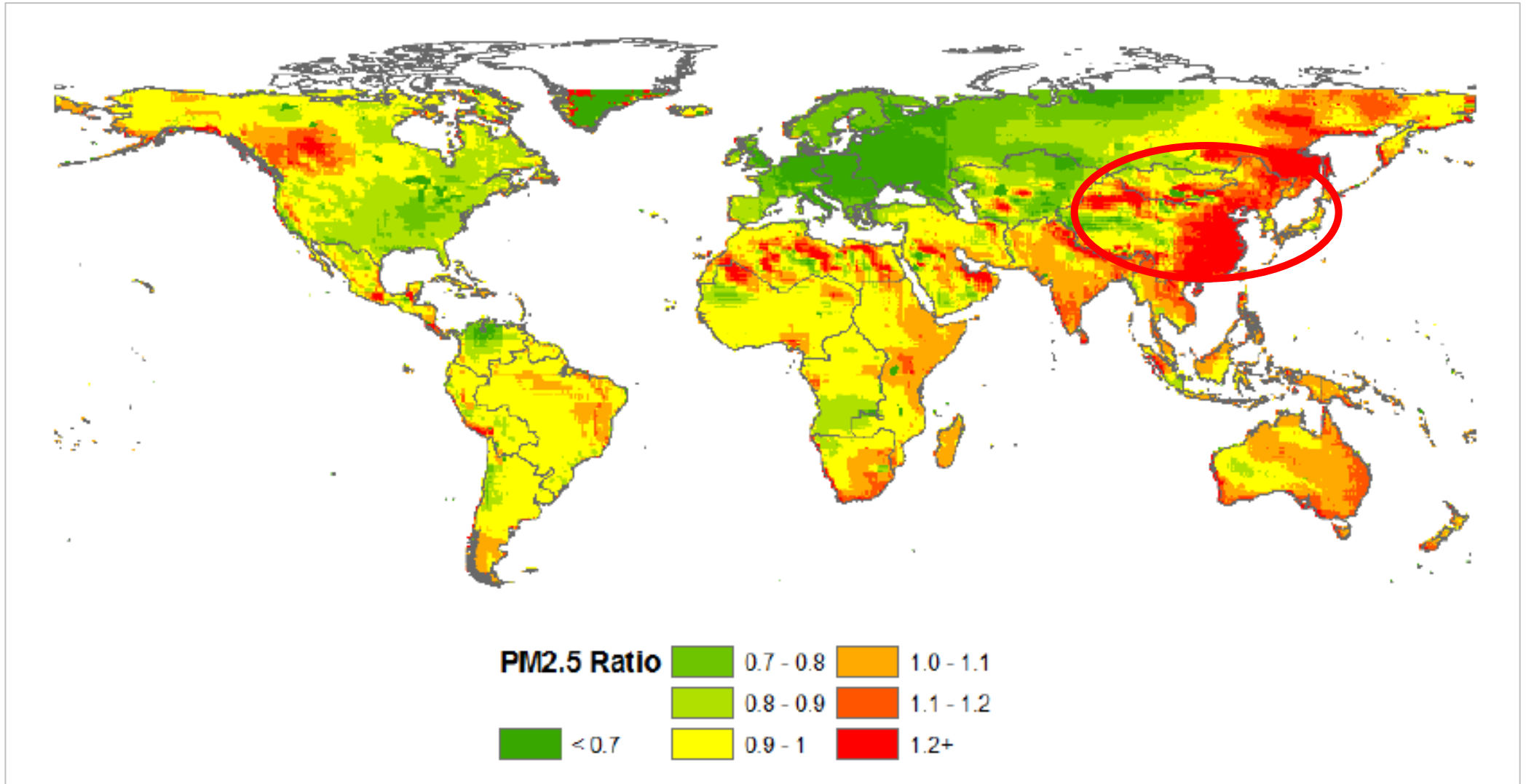
**Population-weighted PM_{2.5} levels in
China: 55 $\mu\text{g}/\text{m}^3$ (annual average)**



Satellite-Derived PM_{2.5} [$\mu\text{g}/\text{m}^3$]

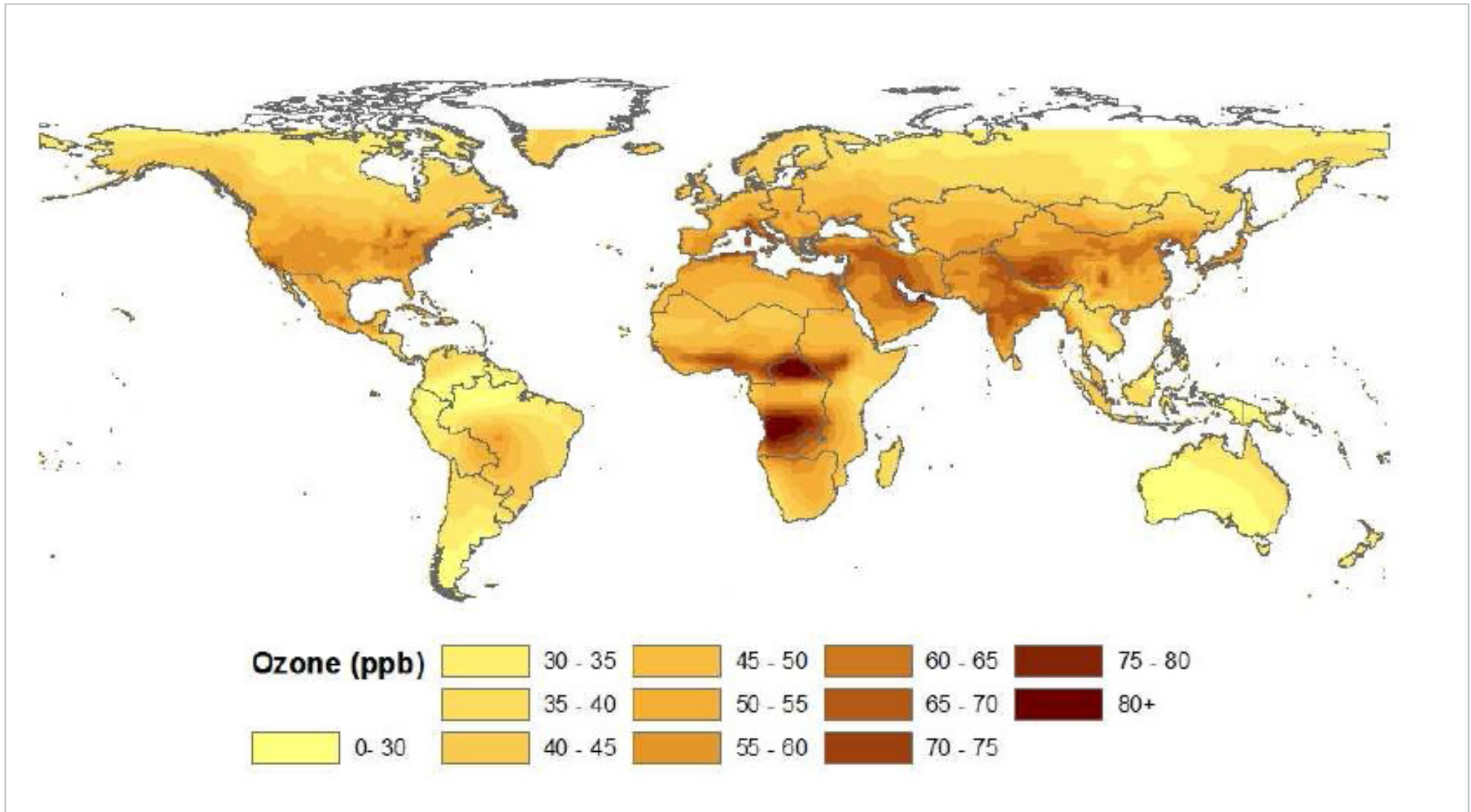
EHP, 2010

Ratio of PM_{2.5} concentrations: 2005/1990



Brauer et al, EST, 2012

Estimated ozone concentrations (2005, ppb)

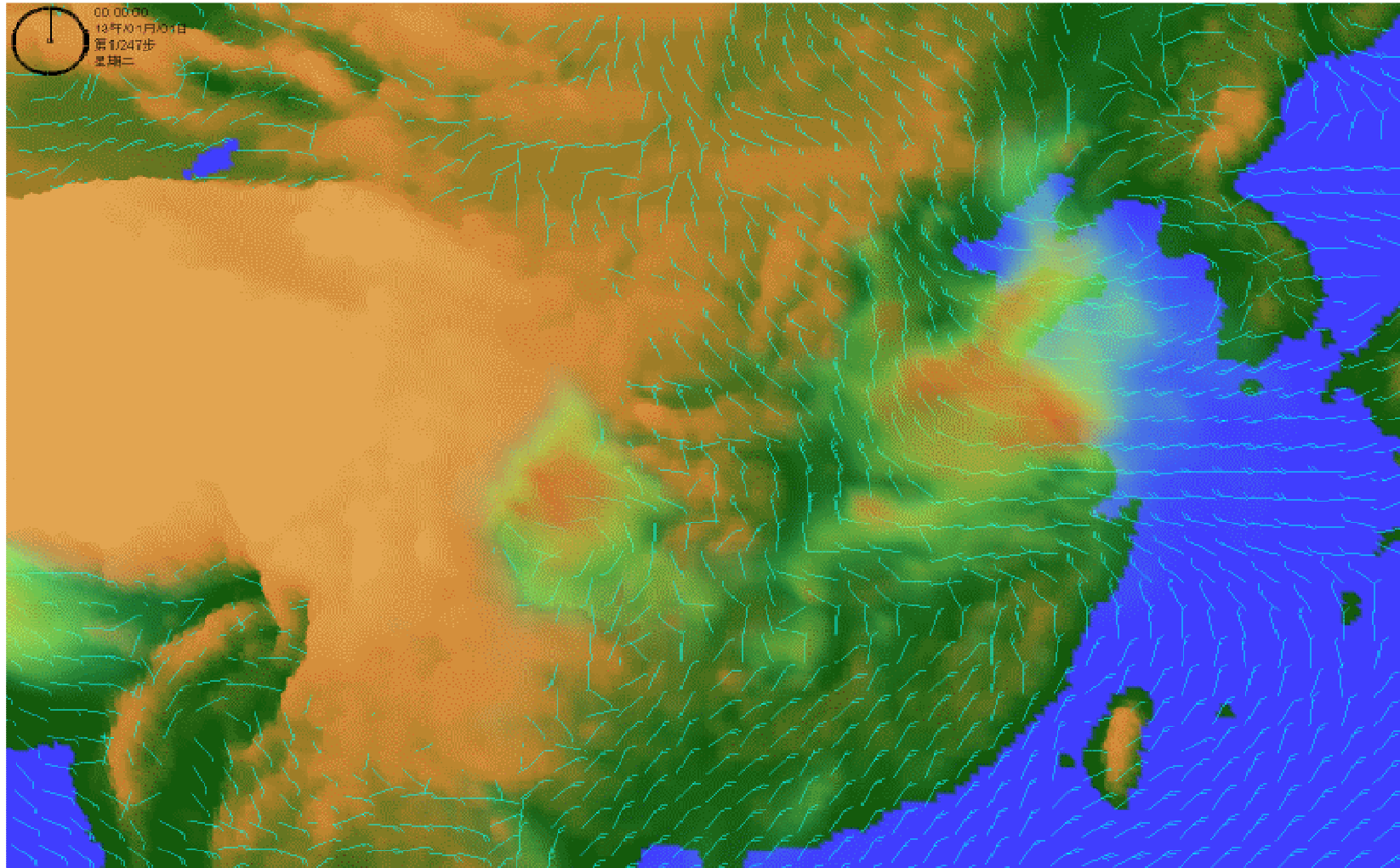


Brauer et al, EST, 2012

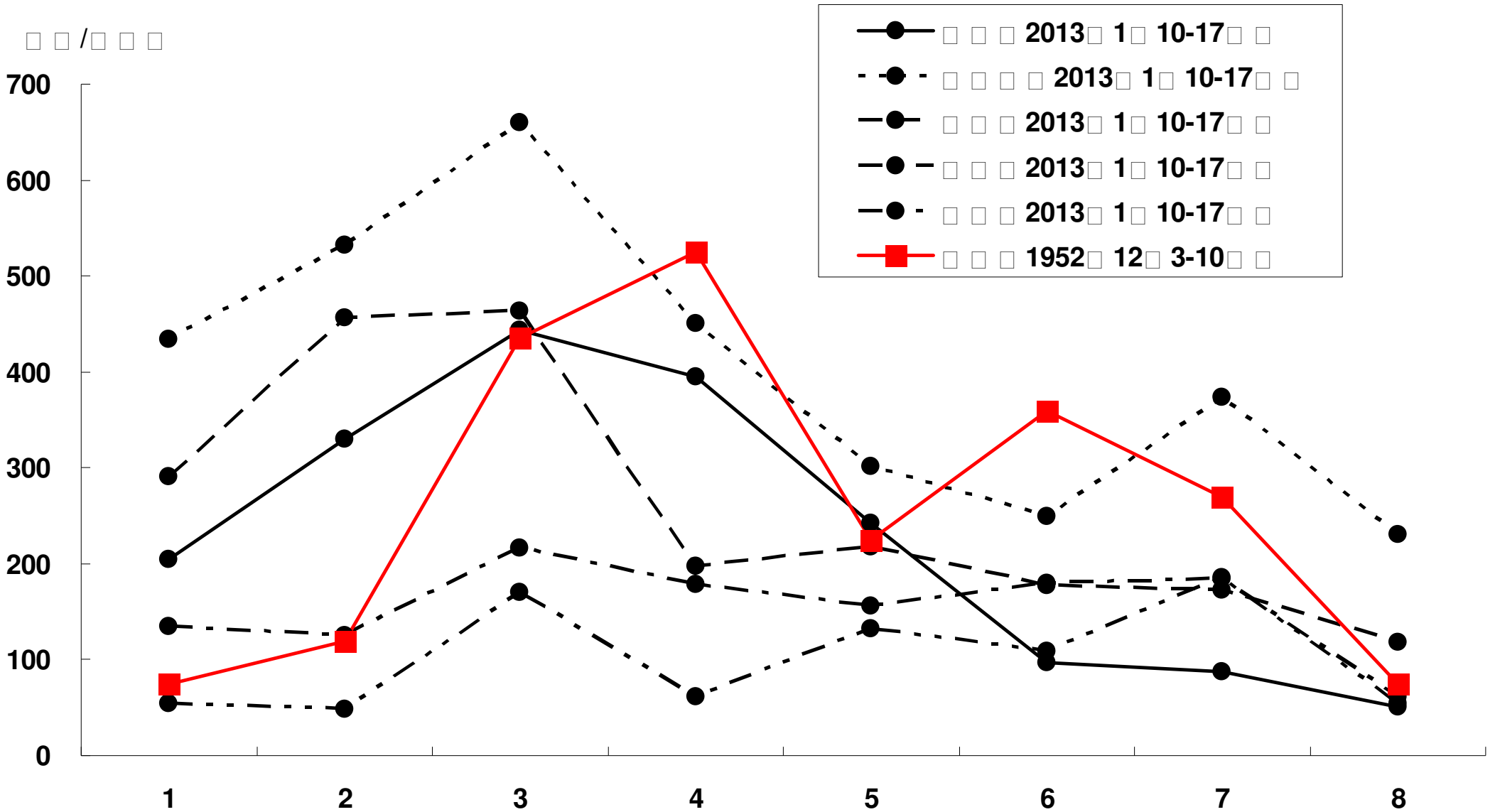
Heavy fog in China January, 2013



Heavy fog in China January, 2013



PM_{2.5} levels during the fog



Global Burden of Disease (2010)

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 Lim¹, Theo Vos¹, Abraham D Frerksen¹, Geodara Demak¹, Kenji Shibuya¹, Heather Adair-Rohani¹, Marius Ammann¹, H Ross Anderson¹, Kathryn G Andrews¹, Martin Arjen¹, Charin Attarasonee¹, Louise Bacon¹, Adán Bahari¹, Kapane Bolanlehin¹, John Balmes¹, Suzanne Barlow-Gale¹, Amanda Baxter¹, Michiel B. B. van den Biggelaar¹, Fiona Blythe¹, Corinne Boucher¹, Guilherme Borges¹, Rupert Bourne¹, Michel Boussineq¹, Michael Brauer¹, Peter Brucher¹, Nigel G Bruce¹, Ben Brusseini¹, Claire Bryson-Hancock¹, Chiara Bucelli¹, Rachelle Buchbinder¹, Fiona Bui¹, Richard T Burnett¹, Tim E Byers¹, Bianca Cabral¹, Jonathan Capoen¹, Emily Carnahan¹, Zee Chafiq¹, Fiona Charlson¹, Hongbin Chen¹, Jian Shen Chen¹, Andrew Tai Ann Cheng¹, Jennifer Christine Child¹, Aaron Cohen¹, K Elicott Colwell¹, Benjamin C Cowie¹, Sarah Darby¹, Susan Darling¹, Adrian Davis¹, Louisa Degenhardt¹, Frank Dentener¹, Don C Des Jarlais¹, Karen Devries¹, Mubina Dhanraj¹, Eric Ding¹, Ray Dorsey¹, Tim Driscoll¹, Karen Edmond¹, Saad Bhattarai¹, Rebecca E Engle¹, Patricia Erwin¹, Saman Fakhireh¹, Gail Falder¹, Farhad Farzafshan¹, Alise Farahi¹, Maria F Ferraz¹, Seth Flaxman¹, Francis Garry¹, Ryan Geary¹, Greg Gerszten¹, Michael K Freeman¹, Emmanuel Galidou¹, Senta Ghahai¹, Edward Giovannucci¹, Gerhard Gmel¹, Kathryn Graham¹, Rebecca Granger¹, Bridget Grant¹, David Gunnell¹, Hilary Gutierrez¹, Wayan Hailu¹, Hans W Hilderink¹, Anthony Hilderink¹, H Dean Hogood¹, Davian Hoyt¹, Howard Hu¹, Bryan Hubbell¹, Sally Hunsicker¹, Sydney El-behus¹, Gemma J Jacolly¹, Rashmi Jaisankar¹, Joe Jonas¹, Haidong Kan¹, John A Kanis¹, Nicholas Kaszubowski¹, Norito Kawakami¹, Young-Ho Khang¹, Shahab Khatibzadeh¹, Jian-Paul Khoo¹, Gail Kelly¹, Francine Laden¹, Rabih Lalloua¹, Qing Lan¹, Tim Lathlean¹, Janet L Leach¹, Jenni Leight¹, Yongli Li¹, John Kent Lin¹, Steven E Lipschutz¹, Stephanie Linder¹, Rafael Lora¹, Yuan Lu¹, Jodie Maller¹, Ross Malarialdi¹, Leslie Malinger¹, Wagner Marcom¹, Lynn March¹, Robin Martin¹, Randall Mason¹, Paul McGee¹, John McGrath¹, Sumit Mohan¹, George A Mouskas¹, Tony R Murren¹, Renato Mocha¹, Catherine Mouchau¹, Vinod Mishra¹, Khayryyah Mohd Haniffah¹, Aïda Mokdad¹, Lidia Morawala¹, Darush Mozaffarian¹, Tasha Murray¹, Mahesh Naghavi¹, Bruce Neal¹, Paul Nishiura¹, Jean Miguel Nolla¹, Rosane Norman¹, Casey Oliver¹, Sead B Okun¹, Jia Liza Othman¹, Richard Othman¹, Bart Oron¹, Andrew Page¹, Kiran D Pandey¹, Charin DH Pany¹, Erin Passmore¹, Jigajep Pabon¹, Neil Pearce¹, Pamela M Peltzer¹, Marc Peltzer¹, Michael P Hillier¹, Dan Pope¹, Carole Poppe¹, John Powell¹, Miquela Post¹, Florine Ravaei¹, Eva A Reyher¹, Jürgen T Reher¹, Beate Ritz¹, Frederic P Rivara¹, Thomas Roberts¹, Carolyn Robinson¹, Jose A Rodriguez-Flores¹, Isabella Romieu¹, Robin Room¹, Lisa C Rossfeld¹, Ayanza Roy¹, Lesley Rutzos¹, Joshua A Salomon¹, Uchchokunwa Sampson¹, Lidia Sanchez-Kawir¹, Eric Saravali¹, Amir Sepkowitz¹, Sonja Seidler¹, Paul Shih¹, Kevin Shih¹, Rajeev Shrivastava¹, Gopal M Singh¹, David A Sliker¹, Emma Smith¹, Kati R Smith¹, Nicolaus C Stangenberg¹, Kyle Steenland¹, Heidi Steiner¹, Larifolash Stovner¹, Kurt Straif¹, Lahn Stroney¹, George DT Thurston¹, Jeremy H Tost¹, Rita Ven Dingenen¹, Aaron van Damme¹, J Lennert Vermeulen¹, Lalithra Vijayarajasekaran¹, Robert Weintraub¹, Myranda Weissman¹, Richard A White¹, Harvey Whiteford¹, Simon T Williams¹, James DW Wilson¹, Piyal CW Wilson¹, Warwick Williams¹, Nicholas Wilson¹, Anthony D Wood¹, Paul Yip¹, Jan M Zanardi¹, Alan D Lopez¹, Christlpher J L Murray¹, Majid Ezzati¹

Summary Background Quantification of the disease burden caused by different risks informs prevention by providing an account of health loss different to that provided by a disease-by-disease analysis. No complete revision of global disease burden caused by risk factors has been done since a comparative risk assessment in 2000, and no previous analysis has assessed changes in burden attributable to risk factors over time.

Methods We estimated deaths and disability-adjusted life years (DALYs; sum of years lived with disability [YLD] and years of life lost [YLL]) attributable to the independent effects of 67 risk factors and clusters of risk factors for 21 regions in 1990 and 2010. We estimated exposure distributions for each year, region, sex, and age group, and relative risks per unit of exposure by systematically reviewing and synthesizing published and unpublished data. We used these estimates, together with estimates of cause-specific deaths and DALYs from the Global Burden of Disease Study 2010, to calculate the burden attributable to each risk factor exposure compared with the theoretical minimum-risk exposure. We incorporated uncertainty in disease burden, relative risks, and exposures into our estimates of attributable burden.

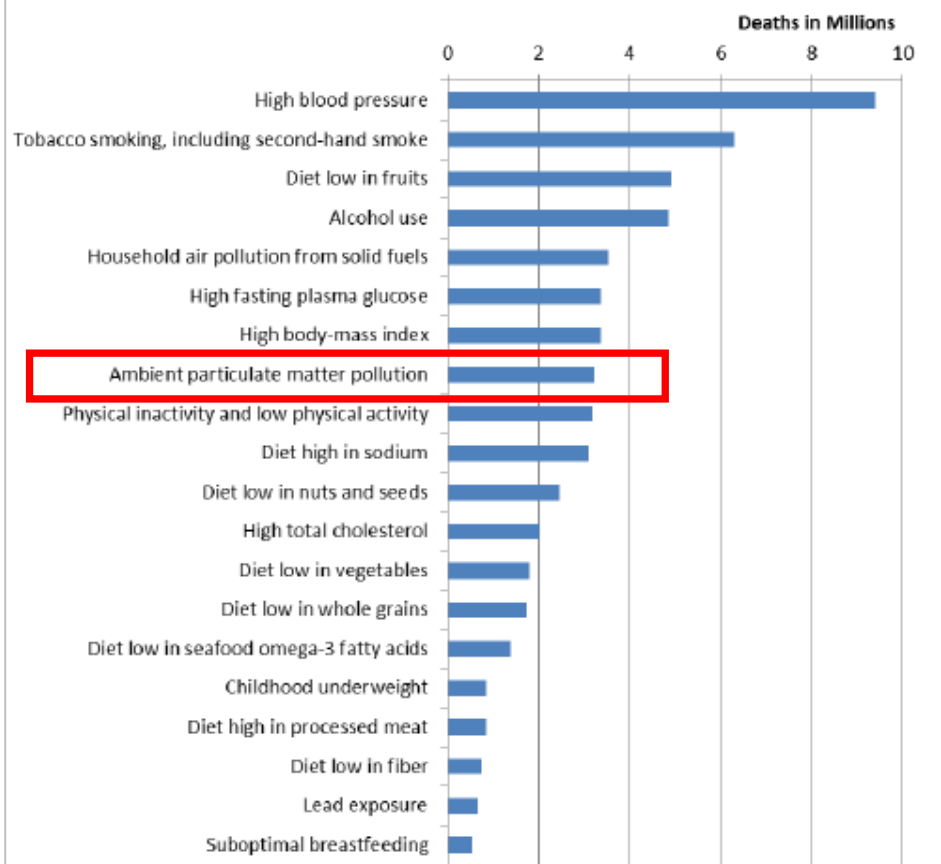
Findings In 2010, the three leading risk factors for global disease burden were high blood pressure (7.09% [95% uncertainty interval 6.2–7.7] of global DALYs), tobacco smoking including second-hand smoke (6.39% [5.7–7.0]), and alcohol use (5.3% [5.0–5.9]). In 1990, the leading risks were childhood underweight (7.9% [6.8–9.4]), household air pollution from solid fuels (HAP; 7.09% [5.4–8.3]), and tobacco smoking including second-hand smoke (6.1% [5.4–6.8]). Dietary risk factors and physical inactivity collectively accounted for 10.0% (95% UI 9.2–10.8) of global DALYs in 2010, with the most prominent dietary risks being diet low in fruits and those high in sodium. Several risks that primarily affect childhood communicable diseases, including unimproved water and sanitation and childhood micronutrient deficiencies, fell in rank between 1990 and 2010, with unimproved water

Lancet 2012, 380: 2224–60
See Comment page 2025, 2026, 2027, 2028, 2029, 2030, 2031, and 2032
See Special Report page 2033
See Article page 2035, 2036, 2037, 2038, 2039, and 2040
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See Online for appendix
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Lim et al, Lancet, 2012

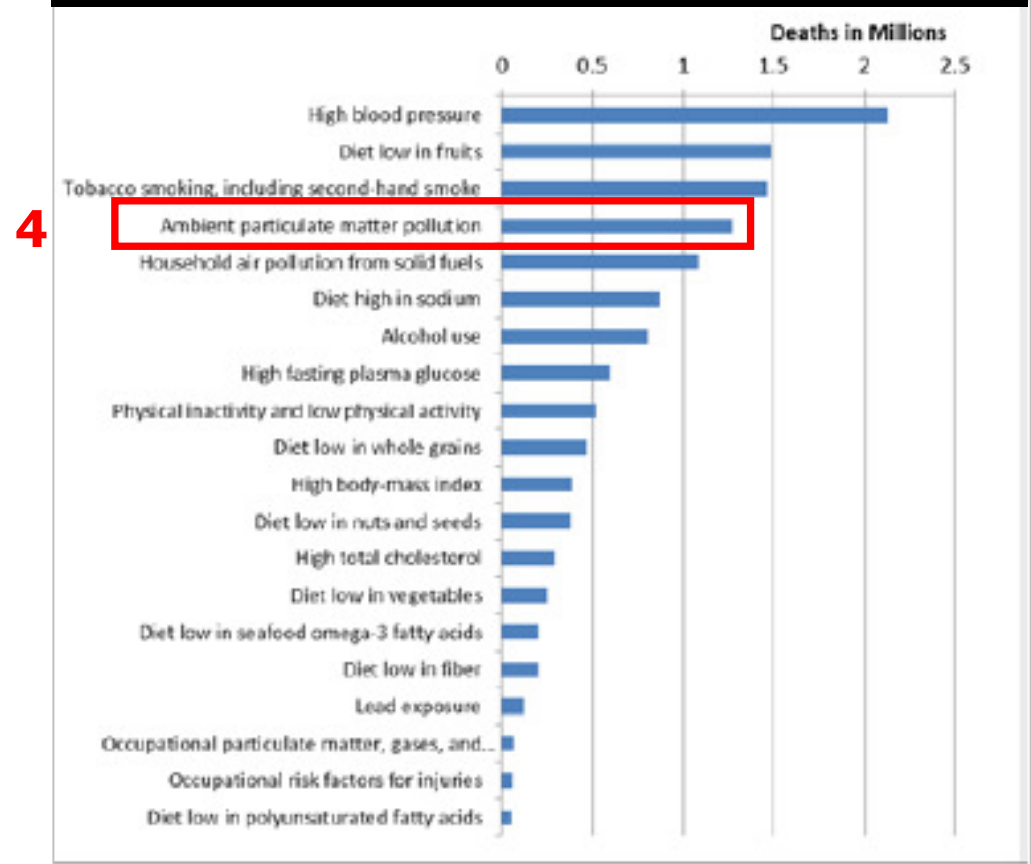
Top 20 risk factors for mortality

Global



8

China



4

Lim et al, Lancet, 2012

PM_{2.5} and ALRI

Mean PAF- ALRI- 2010- Mortality

04/25/12

30%

- | | |
|-------------|-------------|
| 0-0.004 | 0.1-0.13 |
| 0.004-0.009 | 0.13-0.153 |
| 0.009-0.035 | 0.153-0.173 |
| 0.035-0.066 | 0.173-0.207 |
| 0.066-0.1 | 0.207-0.401 |

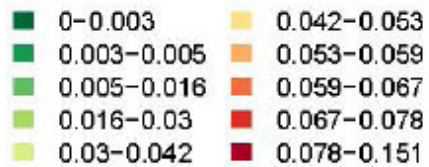
GBD, 2012

PM_{2.5} and COPD

Mean PAF- Chronic obstructive pulmonary disease- 2010- Mortality

04/25/12

11%

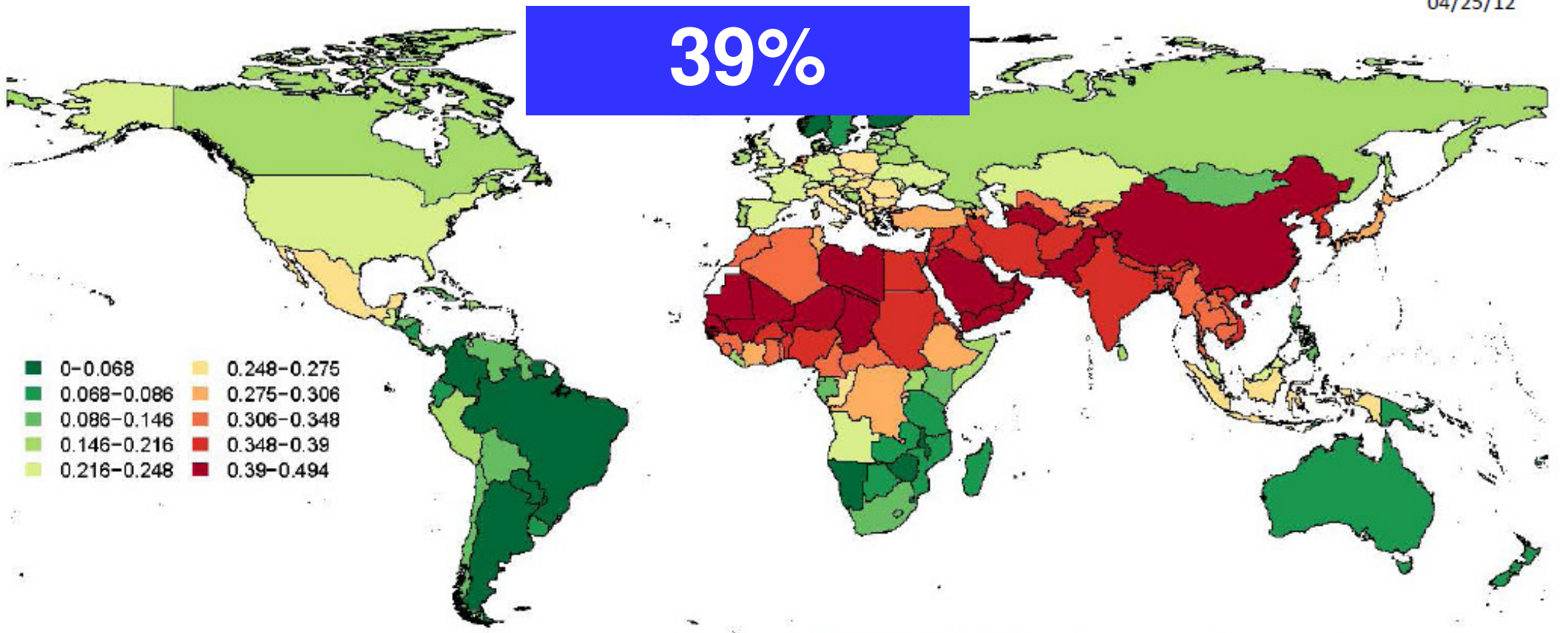


GBD, 2012

PM_{2.5} and CHD

Mean PAF– Ischemic heart disease– 2010– Mortality

04/25/12



GBD, 2012

PM_{2.5} and stroke

Mean PAF– Hemorrhagic and other non–ischemic stroke– 2010– Mortality

04/25/12

45%

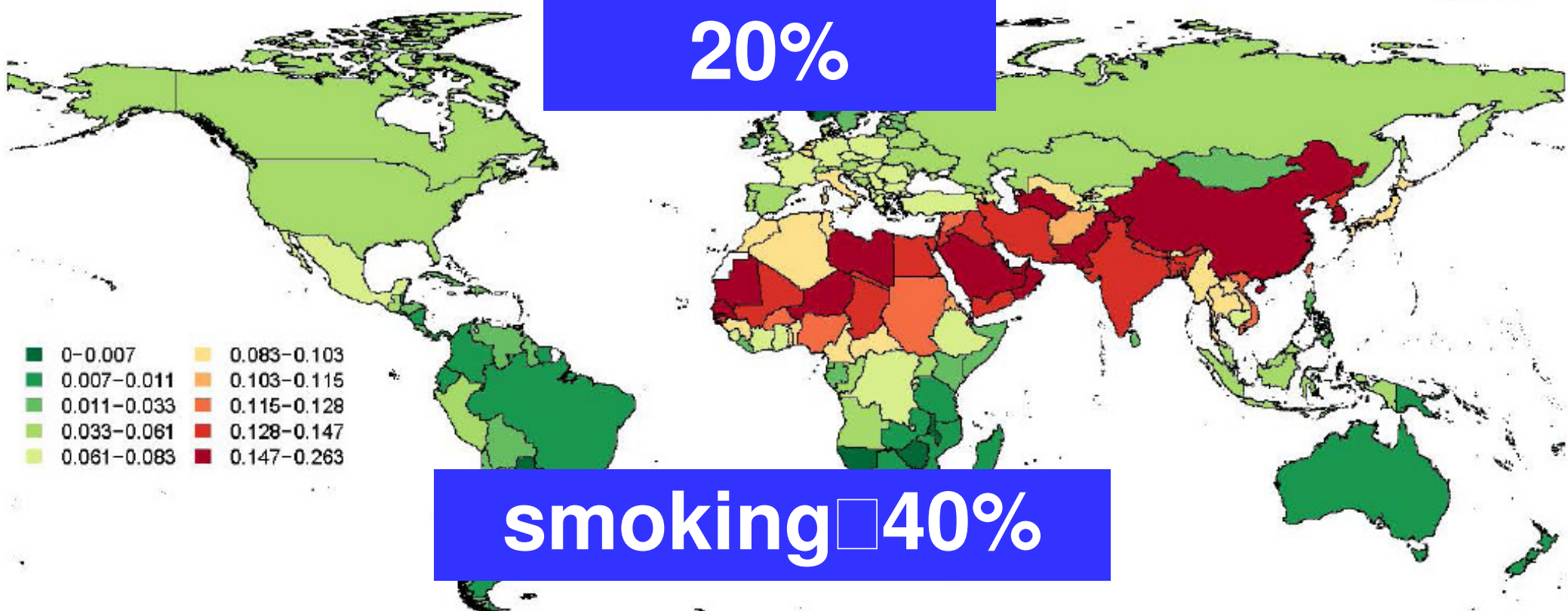


GBD, 2012

PM_{2.5} and lung cancer

Mean PAF– Trachea, bronchus and lung cancers– 2010– Mortality

04/25/12



GBD, 2012

Air pollution research in China

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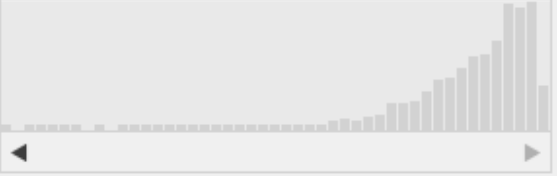
[PM_{2.5} emissions from light-duty gasoline vehicles in Beijing, China.](#)

1. Shen X, Yao Z, Huo H, He K, Zhang Y, Liu H, Ye Y.
Sci Total Environ. 2014 May 5;487C:521-527. doi: 10.1016/j.scitotenv.2014.04.059. [Epub ahead of print]
PMID: 24810889 [PubMed - as supplied by publisher]
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[Biodegradation of C5-C 8 fatty acids and production of aroma volatiles by Myroides sp. ZB35 isolated from activated sludge.](#)

2. Xiao Z, Zhu X, Xi L, Hou X, Fang L, Lu JR.
J Microbiol. 2014 May;52(5):407-12. doi: 10.1007/s12275-014-4109-x. Epub 2014 May 9.
PMID: 24810320 [PubMed - in process]
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A summary of air pollution epidemiologic studies in China

- **Short-term exposure studies**
 - Time-series/case crossover studies
 - Single-city analysis: Beijing, Hong Kong, Shanghai, Shenyang, Taiyuan, Wuhan, etc.
 - Multi-city analysis: PAPA, **CAPES**
 - Panel study: Beijing
- **Long-term exposure study**
 - Cross-sectional study: several
 - Cohort study: CNHS-Air
- **Intervention study**
 - Beijing Olympics
 - Hong Kong

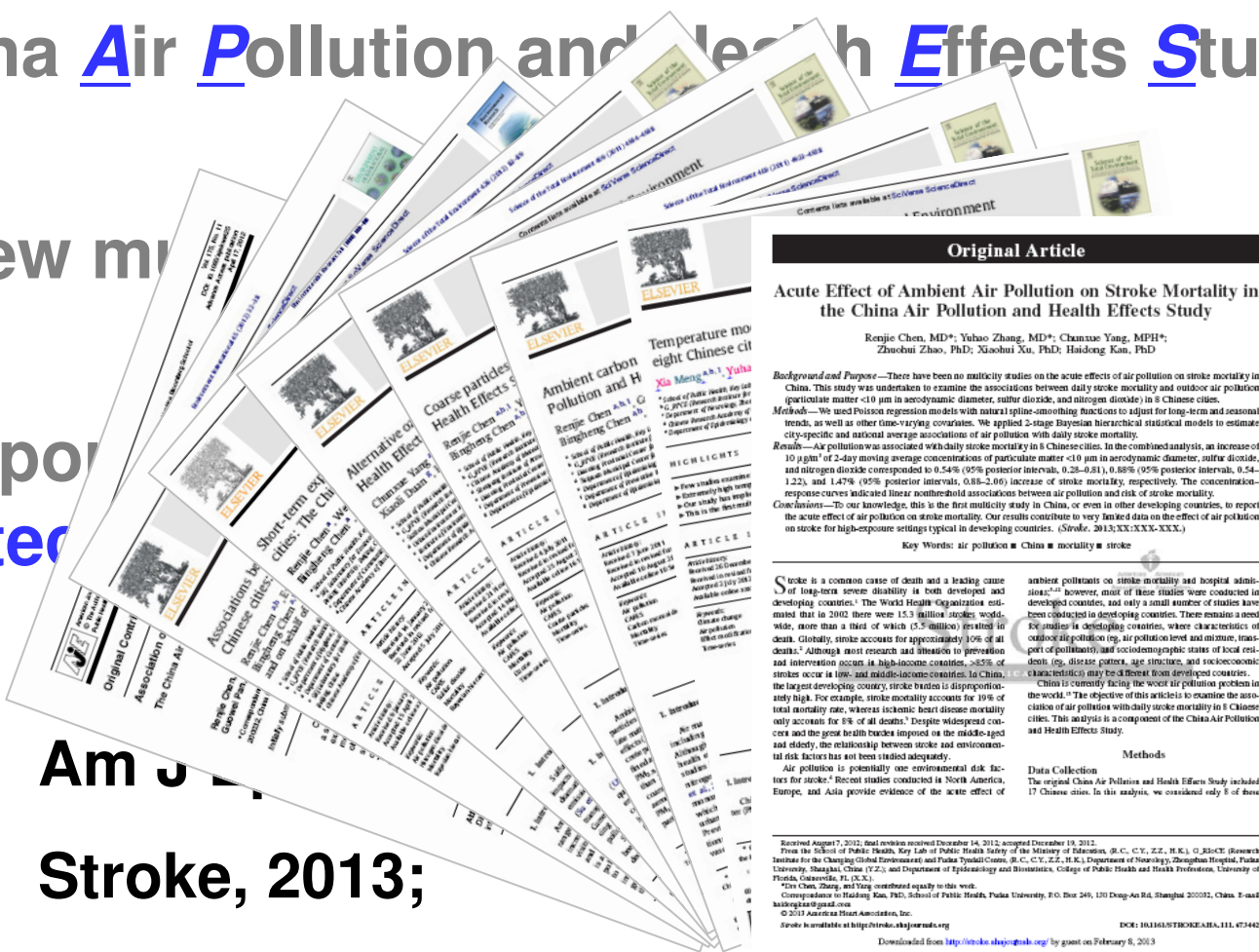
CAPES

- China Air Pollution and Leach Effects Study

- A new m

- Support
- Protec

Am J Stroke, 2013;



Original Article

Acute Effect of Ambient Air Pollution on Stroke Mortality in the China Air Pollution and Health Effects Study

Renjie Chen, MD*, Yuhao Zhang, MD*, Chenxue Yang, MPH*, Zhuohui Zhao, PhD; Xiaohui Xu, PhD; Haidong Kan, PhD

Background and Purpose—There have been no multicity studies on the acute effects of air pollution on stroke mortality in China. This study was undertaken to examine the associations between daily stroke mortality and outdoor air pollution (particulate matter <10 μm in aerodynamic diameter, sulfur dioxide, and nitrogen dioxide) in 8 Chinese cities.

Methods—We used Poisson regression models with natural spline-smoothing functions to adjust for long-term and seasonal trends, as well as other time-varying covariates. We applied 2-stage Bayesian hierarchical statistical models to estimate city-specific and national average associations of air pollution with daily stroke mortality.

Results—Air pollution was associated with daily stroke mortality in 8 Chinese cities. In the combined analysis, an increase of 10 μg/m³ of 2-day moving average concentrations of particulate matter <10 μm in aerodynamic diameter, sulfur dioxide, and nitrogen dioxide corresponded to 0.54% (95% posterior intervals, 0.28–0.81), 0.88% (95% posterior intervals, 0.54–1.22), and 1.47% (95% posterior intervals, 0.88–2.06) increase of stroke mortality, respectively. The concentration-response curves indicated linear nonthreshold associations between air pollution and risk of stroke mortality.

Conclusions—To our knowledge, this is the first multicity study in China, or even in other developing countries, to report the acute effect of air pollution on stroke mortality. Our results contribute to very limited data on the effect of air pollution on stroke for high-exposure settings typical in developing countries. (Stroke. 2013;XX:XXX-XXX.)

Key Words: air pollution ■ China ■ mortality ■ stroke

Stroke is a common cause of death and a leading cause of long-term severe disability in both developed and developing countries.¹ The World Health Organization estimated that in 2002 there were 15.3 million strokes worldwide, more than a third of which (5.5 million) resulted in death. Globally, stroke accounts for approximately 10% of all deaths.² Although most research and attention to prevention and intervention occurs in high-income countries, >85% of strokes occur in low- and middle-income countries. In China, the largest developing country, stroke burden is disproportionately high. For example, stroke mortality accounts for 10% of total mortality rate, whereas ischemic heart disease mortality only accounts for 5% of all deaths.³ Despite widespread concern and the great health burden imposed on the middle-aged and elderly, the relationship between stroke and environmental risk factors has not been studied adequately.

Air pollution is potentially one environmental risk factor for stroke.⁴ Recent studies conducted in North America, Europe, and Asia provide evidence of the acute effect of ambient pollutants on stroke mortality and hospital admissions;^{5–11} however, most of these studies were conducted in developed countries, and only a small number of studies have been conducted in developing countries. There remains a need for studies in developing countries, where characteristics of outdoor air pollution (eg, air pollution level and mixture, transport of pollutants) and sociodemographic status of local residents (eg, disease patterns, age structure, and socioeconomic characteristics) may be different from developed countries.

China is currently facing the worst air pollution problem in the world.¹² The objective of this article is to examine the association of air pollution with daily stroke mortality in 8 Chinese cities. This analysis is a component of the China Air Pollution and Health Effects Study.

Methods

Data Collection
The original China Air Pollution and Health Effects Study included 17 Chinese cities. In this analysis, we considered only 8 of these

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From the School of Public Health, Key Lab of Public Health Safety of the Ministry of Education, (R.-C., C.-Y., Z.-Z., H.-K.), Q. J.-C.; Research Institute for the Changing Global Environment and Peking Tsinghua Center, (R.-C., C.-Y., Z.-Z., H.-K.), Departments of Neurology, Zhongshan Hospital, Peking University, Shanghai, China (Y.-Z.), and Department of Epidemiology and Biostatistics, College of Public Health and Health Professions, University of Florida, Gainesville, FL (X.-X.).
*Renjie Chen, Yuhao Zhang, and Yung contributed equally to this work.
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Stroke is available at <http://stroke.ahajournals.org>. DOI: 10.1161/STROKEAHA.111.473462
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CAPES

CAPES cities



Health and Exposure Data

- **Health outcomes**

- Total and cause-specific mortality (for every city)
- Hospital visits (Shanghai)

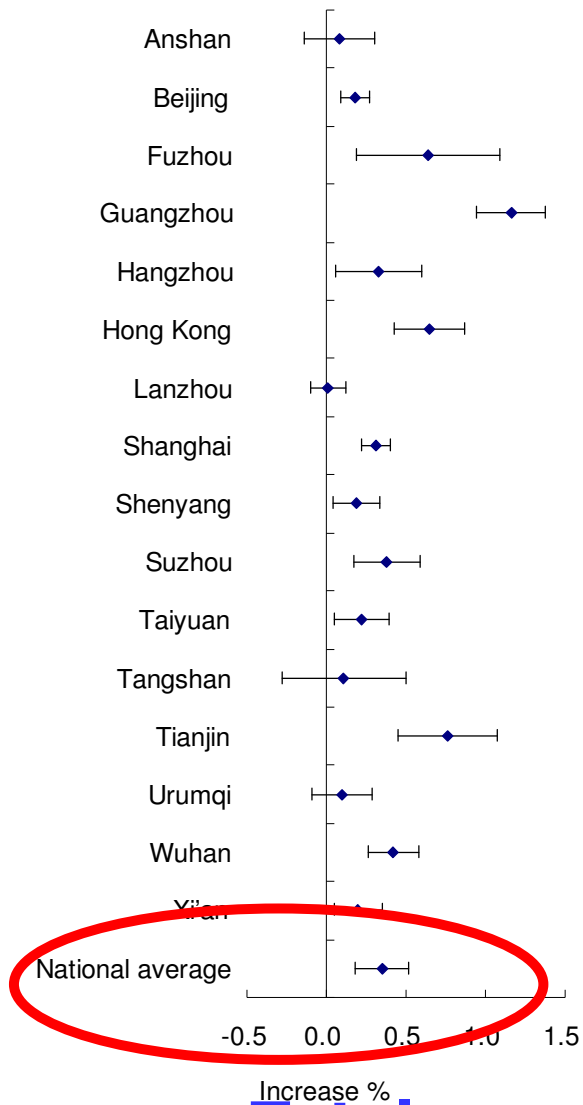
- **Air pollution**

- PM₁₀, SO₂, NO₂ (for every city)
- PM_{2.5} (Beijing, Shanghai, Shenyang, Xi'an, Guangzhou)
- PM_{2.5} components (Xi'an)
- PM_{10-2.5} (Beijing, Shanghai, Shenyang)
- BC (Shanghai)
- O₃ (Shanghai, Suzhou)
- CO (Shanghai, Anshan, Taiyuan)
- Visibility (Shanghai)

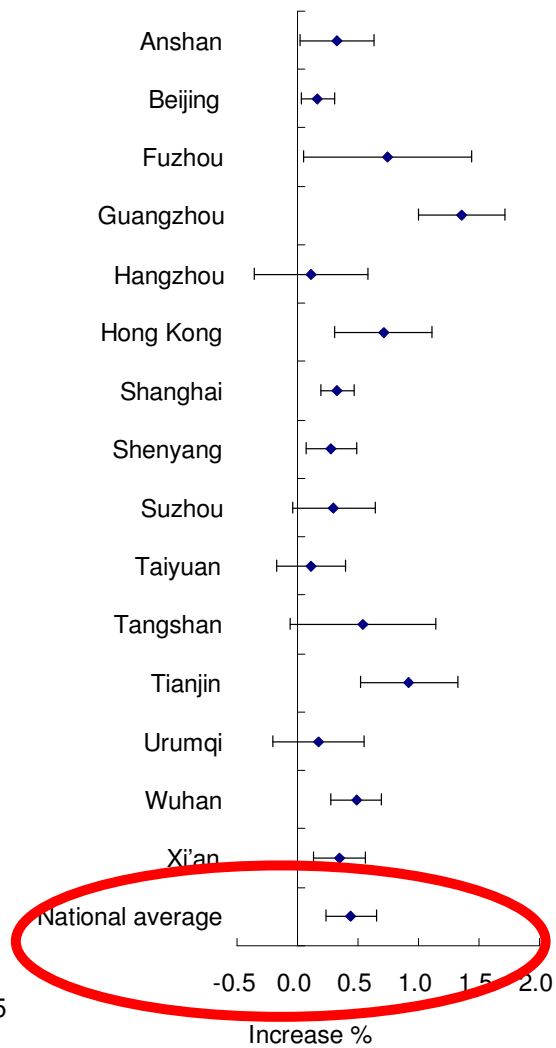
CAPES study: what will it contribute to policy making in China?

- **Robustness of time-series study risk estimates**
- **New evidence of the national C-R function**
- **Comparison of risk estimates gained from China and developed countries**
- **Regional/city variability in results: source apportionment**
- **Does threshold exist**

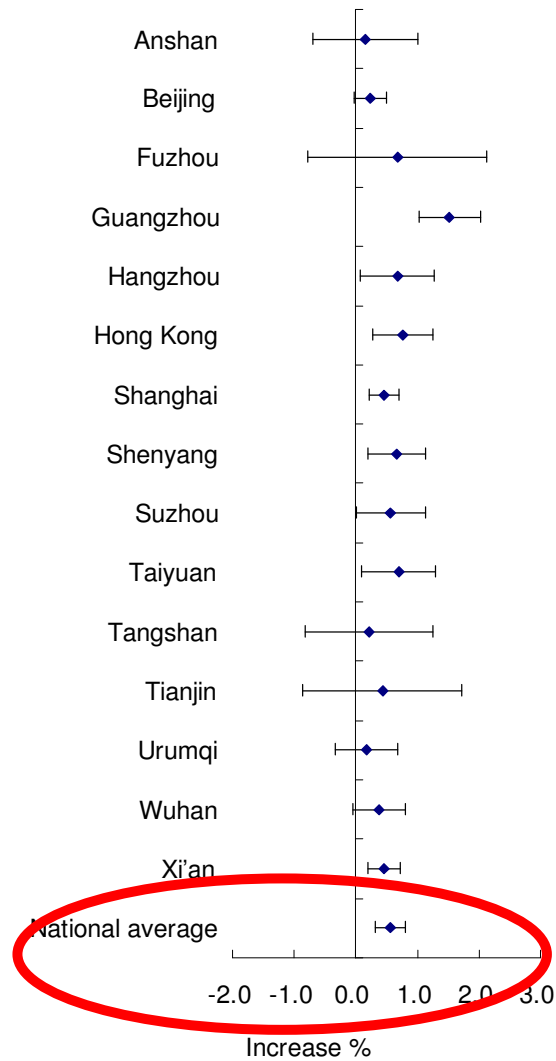
Effects of PM₁₀ in the CAPEs cities



Total mortality

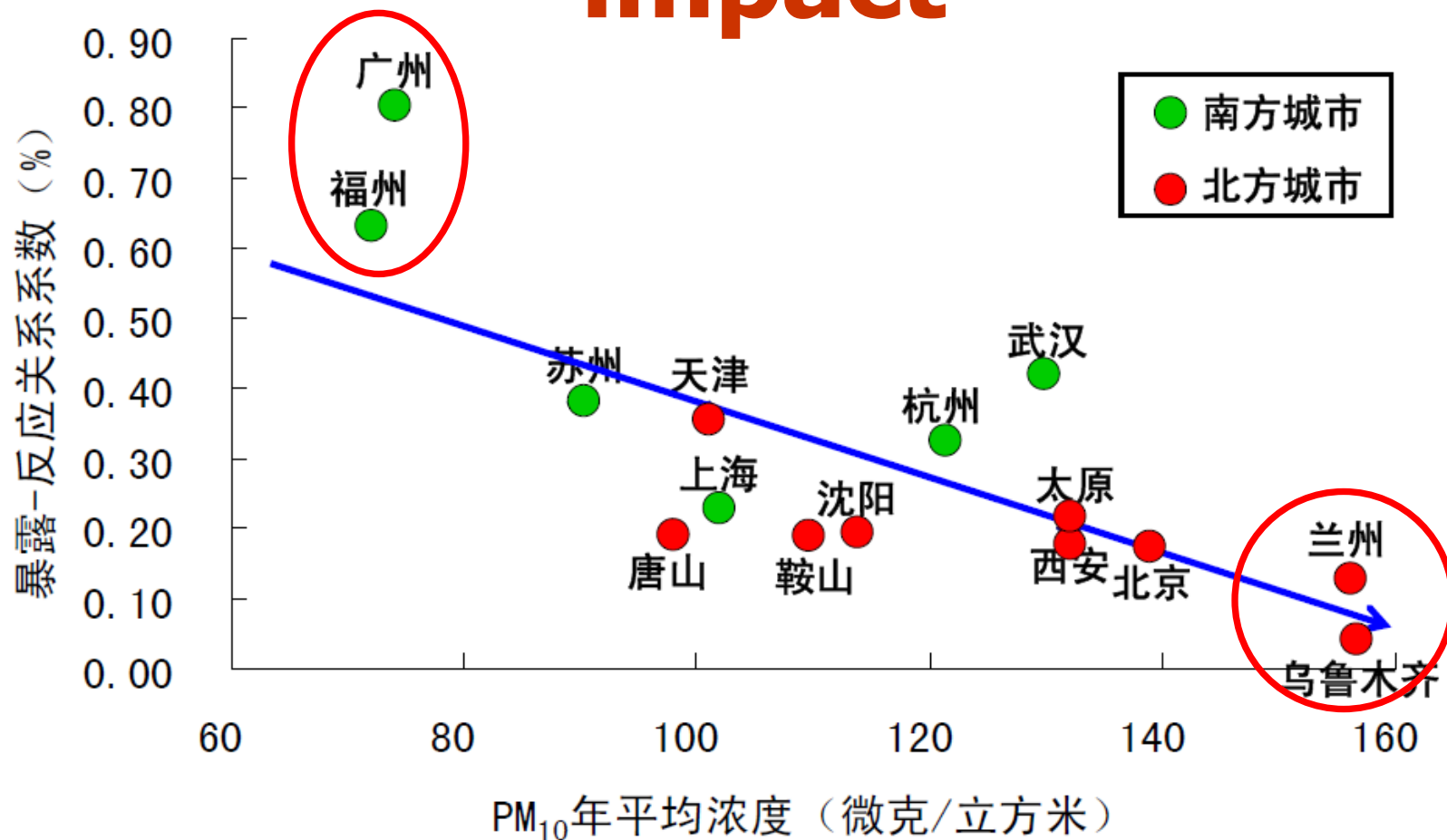


Cardiovascular mortality

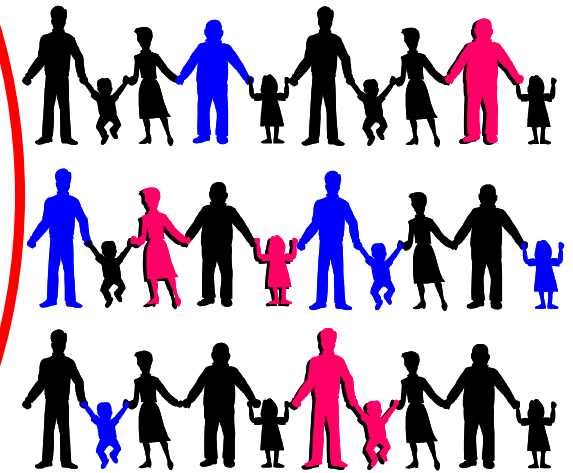
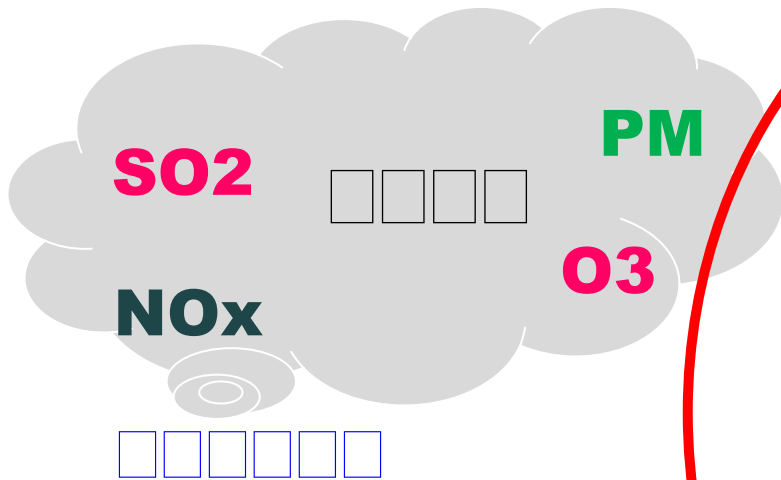


Respiratory mortality

Regional pattern of PM₁₀ health impact



Possible reasons of regional pattern



- □ □ □ □
- □ □ □ □ □ □

□ □ □ □

(□ □ 90% □ □ □ □ □ □)

□ □ □ □ □ □

Regional pattern: a potential role of indoor exposure to outdoor PM₁₀

PM₁₀
= (to

Investigating the geographic associations in the China (CAPES): A potential role of indoor exposure to outdoor PM₁₀

Bin Zhou^a, Bin Zhao^{a*}, Xuefei Zhou^a

^aDepartment of Building Science, School of Architecture, Tongji University, Shanghai, China

HIGHLIGHTS

- We define PM₁₀ exposure coefficient to estimate indoor exposure to outdoor PM₁₀
- Correlation between exposure and mortality
- A strong correlation is found indicating the potential role of indoor exposure to outdoor PM₁₀
- Sensitivity analysis shows good robustness
- PM₁₀ exposure coefficient can partially explain the regional pattern

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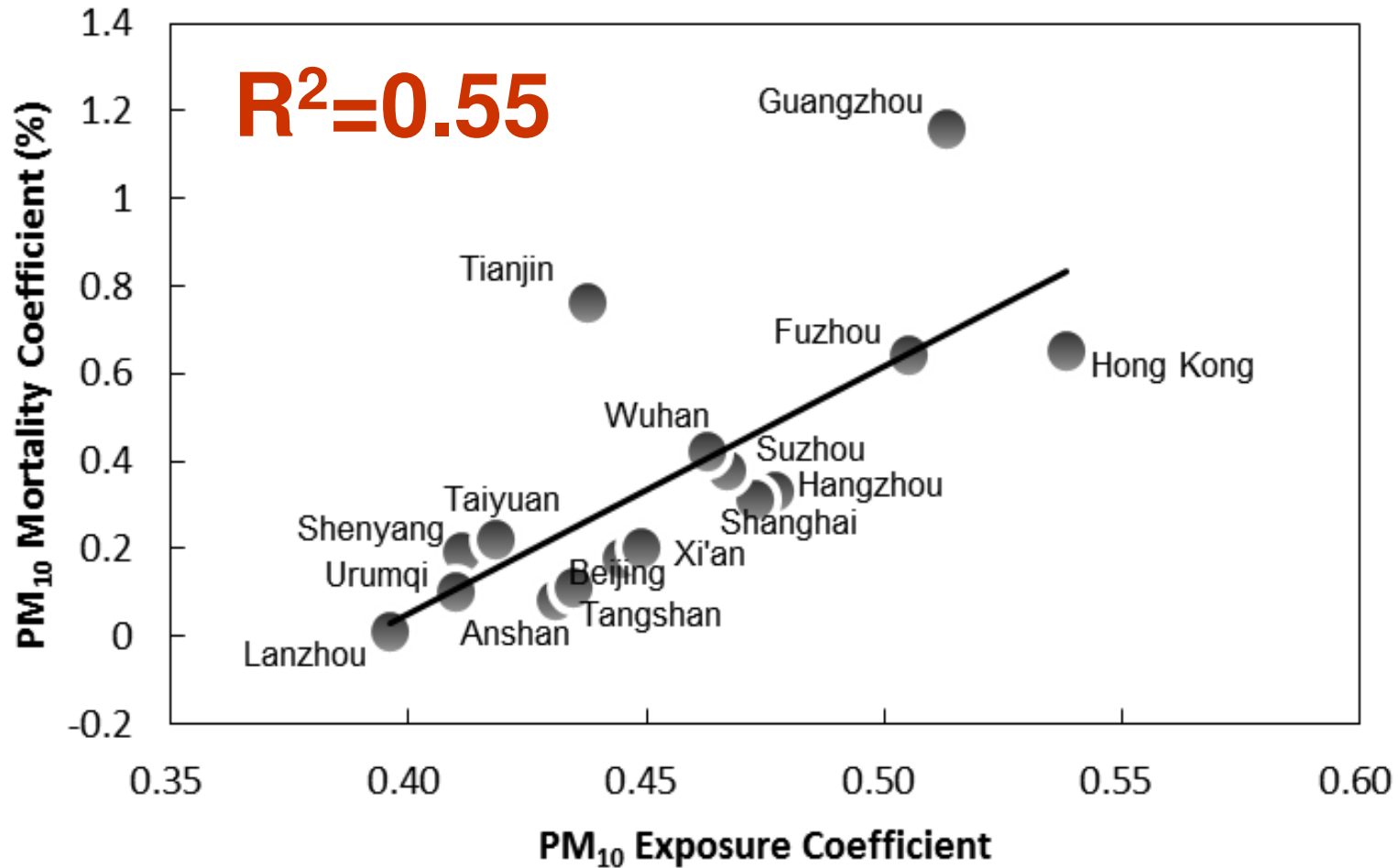
Keywords:
Air change rate
Air conditioning
Outdoor-to-indoor
Particulate matter
Exposure measurement error

1. Introduction

China is currently one of the countries with the highest concentration of particulate matter (PM) concentration (Dankelar et al., 2010). However, only a few studies have examined the related health effects.

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E-mail address: binzhao@tongji.edu.cn (B. Zhao).

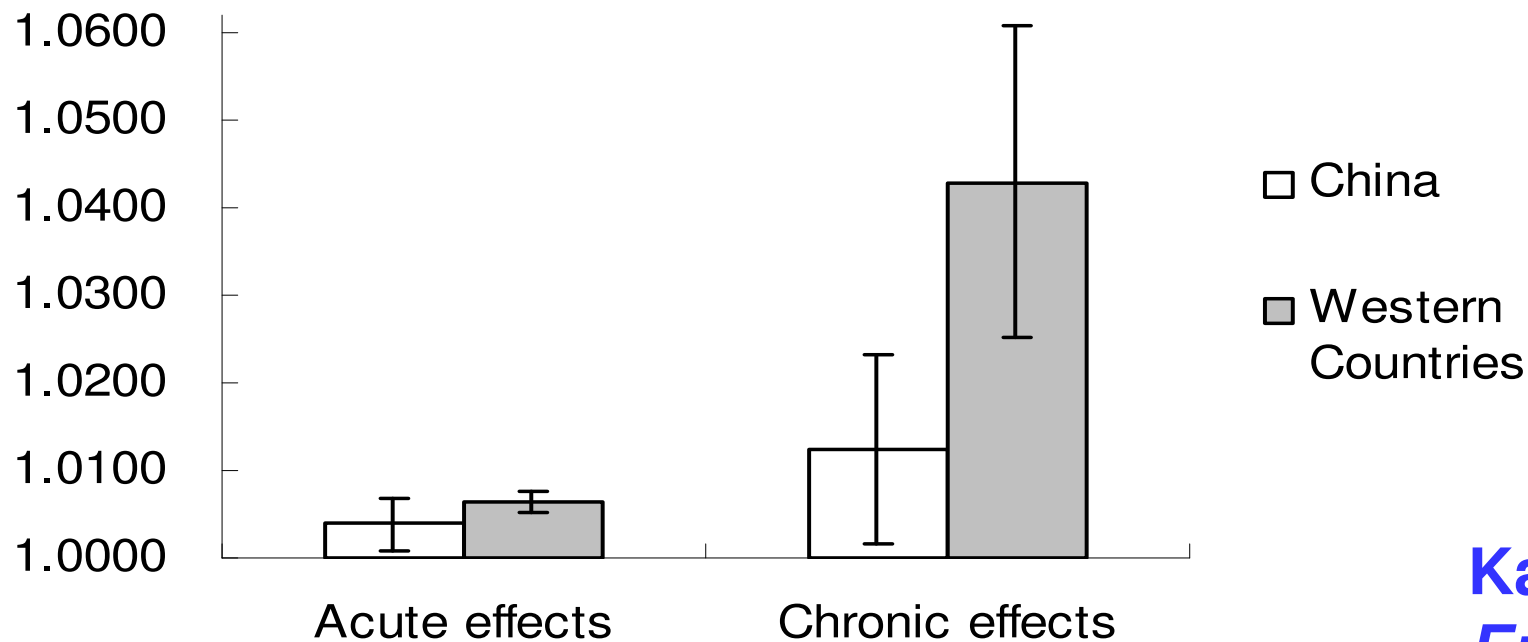
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Establishment of Exposure-response Functions of Air Particulate Matter and Adverse Health Outcomes in China and Worldwide¹

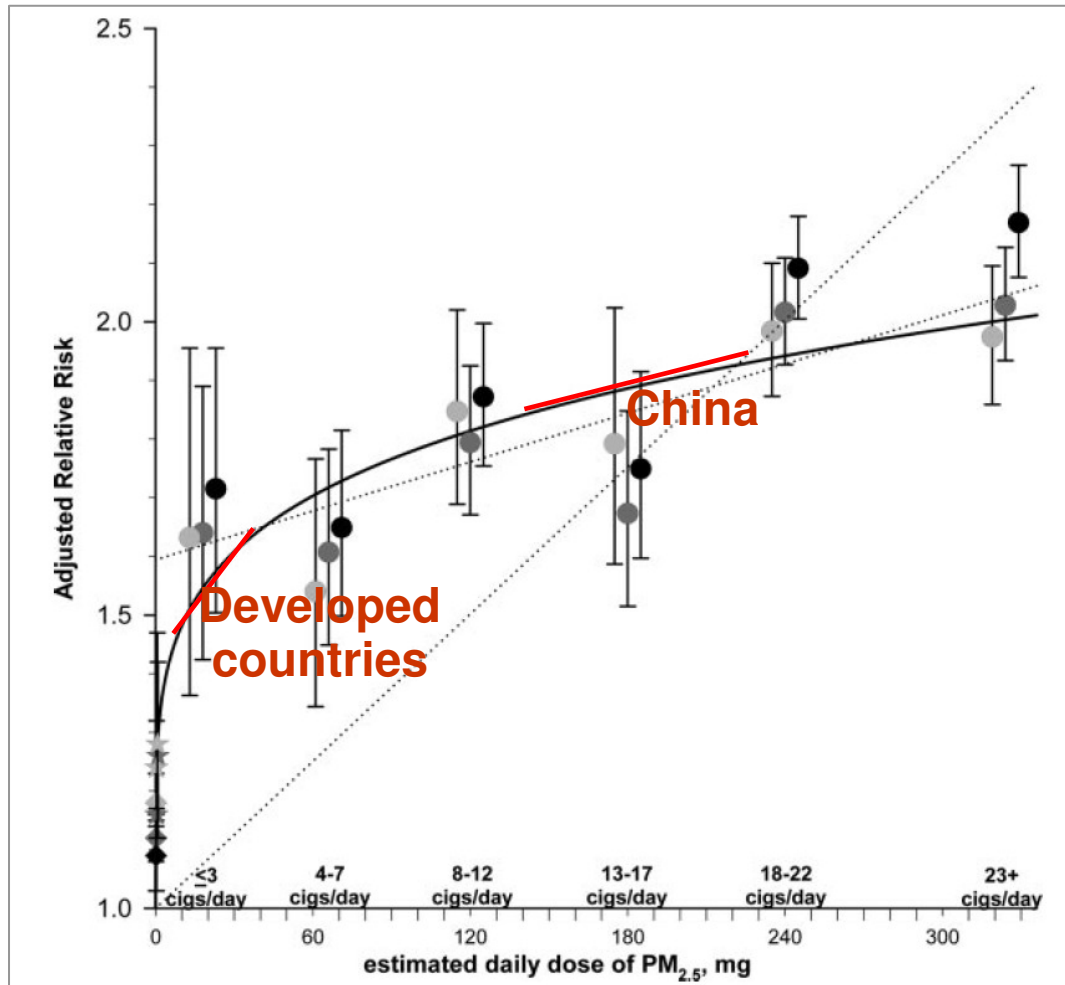
HAI-DONG KAN^{*,2}, BING-HENG CHEN^{*}, CHANG-HONG CHEN[#],
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Kan et al, *Biomed Environ Sci*, 2005

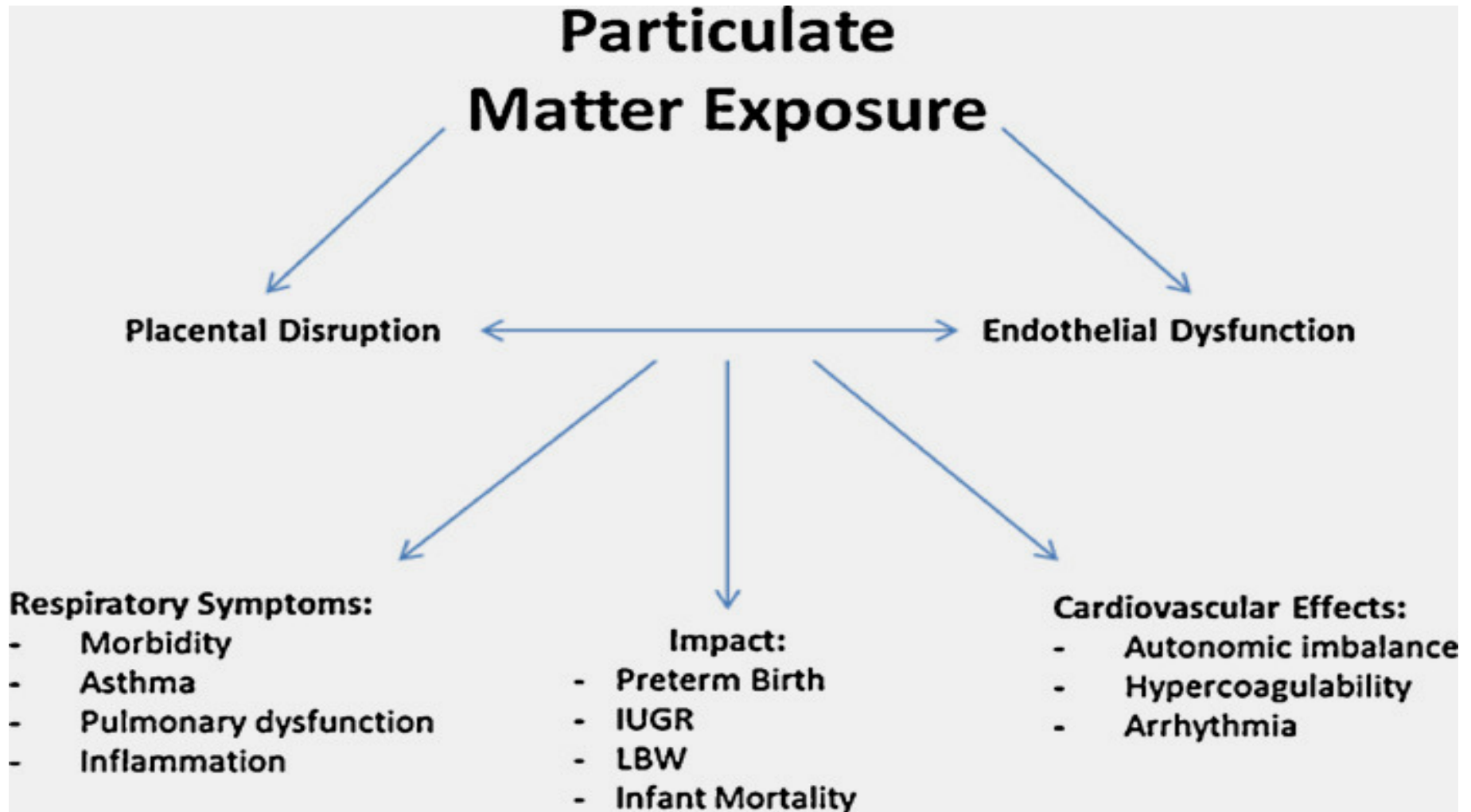
Possible reasons for the smaller effects in Chinese cities



Pope et al, Circulation, 2009

Most Chinese studies focus on the cardiorespiratory system, and few examine the reproductive outcomes

Mechanisms of effect following PM exposure: oxidative stress



Air Pollution and Low Birth Weight in Beijing (Wang et al, EHP, 1997)

- **Design:** a cohort of all pregnant women in four areas in Beijing between 1989-1991, 74,671 first-parity live births with gestational age 37-44 weeks
- **Outcome:** preterm birth, low birth weight
- **Statistical methods:** Multiple linear regression and logistic regression, adjusting for gestational age, residency, year of birth, maternal age, and infant gender.
- **Results:** Significant associations of SO₂ and TSP during the 3rd trimester and low birth weight

Petrochemical exposure with spontaneous abortion in Beijing (Xu et al, OEM, 1998)

- **Design:** a retrospective epidemiological study, 2853 (93%) of the women in a large petrochemical complex in Beijing
- **Outcome:** spontaneous abortion during the first pregnancies
- **Statistical methods:** Multiple logistic regressions
- **Results:** significant increase of spontaneous abortion for women working in all of the production plants with frequent exposure to petrochemicals (8.8%; range of 5.8%–9.8%), compared with those working in nonchemical plants (2.2%; range of 0.0%–7.1%).

Air pollution and preterm birth in Shanghai (Jiang et al, BES, 2007)

- **Design:** Birth Registry-based time-series study
- **Outcome:** preterm birth
- **Statistical methods:** Poisson regression with generalized additive model
- **Results:** significant effect of outdoor air pollution only with 8-week exposure before preterm births; not find any significant acute effect of outdoor air pollution on preterm birth in the week before birth.

Air pollution and preterm birth in Guangzhou (Zhao et al, Environ Health, 2011)

- **Design:** Birth Registry-based time-series study
- **Outcome:** preterm birth
- **Statistical methods:** Poisson regression with generalized additive model
- **Results:** significant acute effect (lag 3-4 days) of outdoor air pollution on preterm birth.

出生医学记录单

区(县) 街道(乡) 编号:

Gestational age	Gender of infants	Name of infants	区(县) 街道(乡) 编号:
出生孕周: 周	性别: 男 女	婴儿姓名: 姓 名	住院号: _____
1 单胎 2 双胎 3 多胎	出生地点: _____	出生时间: 年 月 日 时 分	出生体重: 克
出生胎次: _____	出生体重: 克	胎形种类: _____	畸形: 1 无 2 有
Apgar 评分: _____	出生地点分类: 1. 医院 2. 妇幼保健院 3. 家庭 4. 其它	母亲姓名: _____	出生缺陷(Y/N)
文化程度: 1 研究生 2 大学本科 3 大学专科及专科学校 4 中专及中技 5 技工学校 6 高中 7 初中及以下	证件类型: 1. 身份证 2. 军官证 3. 护照	证件类型: 1. 身份证 2. 军官证 3. 护照	
户口地址: 国 省(市) 市(区/县)	工作单位: _____	职业: _____	Occupation of mothers
民族: _____	在沪地址: _____	联系电话: _____	
工作单位: _____	职业: _____	联系电话: _____	
文化程度: 1 研究生 2 大学本科 3 大学专科及专科学校 4 中专及中技 5 技工学校 6 高中 7 初中及以下	在沪地址: _____	联系电话: _____	
户口地址: 国 省(市) 市(区/县)	工作单位: _____	职业: _____	Occupation of fathers
民族: _____	在沪地址: _____	联系电话: _____	
工作单位: _____	职业: _____	联系电话: _____	
G/P	文化程度: 1 研究生 2 大学本科 3 大学专科及专科学校 4 中专及中技 5 技工学校 6 高中 7 初中及以下	在沪地址: _____	
胎次/产次: G /P	胎序: _____ (多胎时填写)	孩次: _____ (所有现存子女中的次序数)	
分娩方式: 1 自然产 2 臀助产 3 臀牵引 4 胎吸 5 产钳 6 剖腹产	在沪时间: 1 >=1年 2 >=半年但<1年 3 <半年 (此选项仅非本市户籍者填写)	年龄: _____	
现居住地址: 国 省(市) 市(区/县)	在沪时间: 1 >=1年 2 >=半年但<1年 3 <半年 (此选项仅非本市户籍者填写)	年龄: _____	
联系电话: _____	胎次/产次: G /P	胎序: _____ (多胎时填写)	
婴儿申报户口地址: 1 父 2 母 3 同现住址	孩次: _____ (所有现存子女中的次序数)	分娩方式: 1 自然产 2 臀助产 3 臀牵引 4 胎吸 5 产钳 6 剖腹产	
填报日期: 年 月 日	现居住地址: 国 省(市) 市(区/县)	联系电话: _____	
注: 此联报疾控中心	婴儿申报户口地址: 1 父 2 母 3 同现住址	联系电话: _____	

接生单位(盖章): _____

Time-series approach omits seasonally-varying exposures and birth outcomes, and thus might be inappropriate in studying the association between air pollution and birth outcomes

Darrow et al, 2009, Epidemiology

Future research needs

- Birth cohort study and air pollution
- PM components and birth outcomes
- Additional data collection for Birth Registry: smoking (A/P), drinking
- Other birth outcomes: birth defects
- **Research opportunity in China:** huge population, high pollution levels, establishment of PM2.5 monitoring network and Birth Registry in the country

Thank you !

Q ?