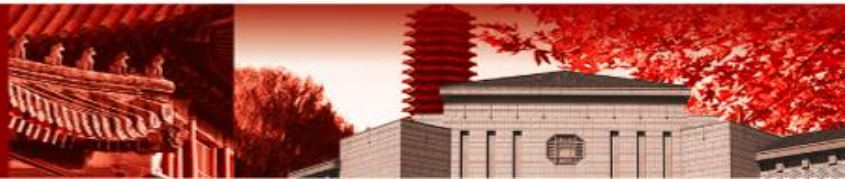
空气污染与人体健康
Air Pollution and Human Health

宫继成 研究员

环境科学与工程学院
环境模拟与污染控制国家重点实验室
北京大学



Content

1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）

Content

1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）

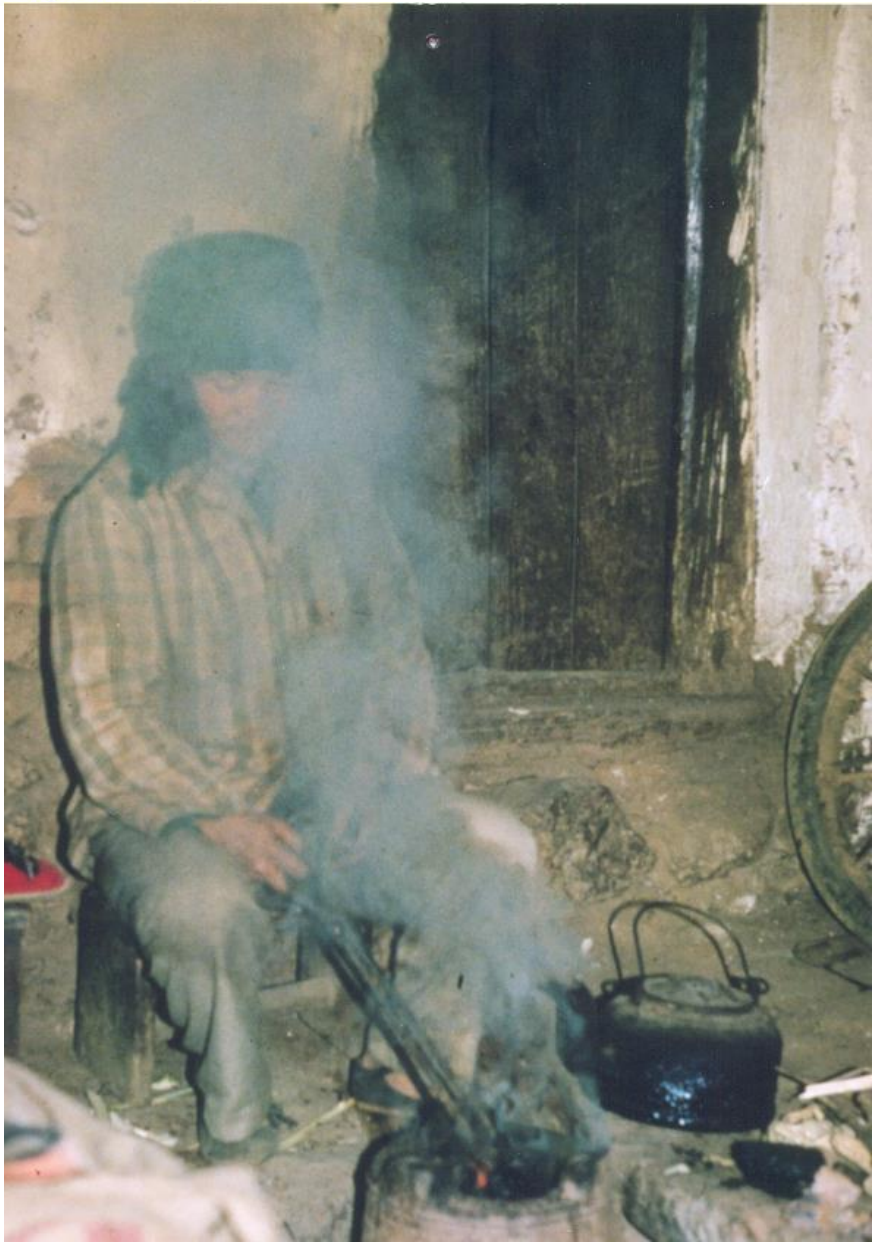
Definitions of Air Pollution

Air pollution is defined "*as any atmospheric condition in which substances are present at concentrations high enough above their normal ambient levels to produce a measurable effect on humans, animals, vegetation, or materials*" (Seinfeld, 1975).

Air Pollution throughout History

- The earliest form of anthropogenic airborne emission is wood smoke.
- Humans have required sources of warmth and cooking fuel for millennia.
- Coal smoke contributed greatly to air pollution problems in the early days of the industrial revolution.
- The “excessive” use of fossil fuels in the modern life causes urban air pollution around the globe and contributes dominantly to the increases in green house gases.

Open-fire biomass cooking is common in developing country villages.

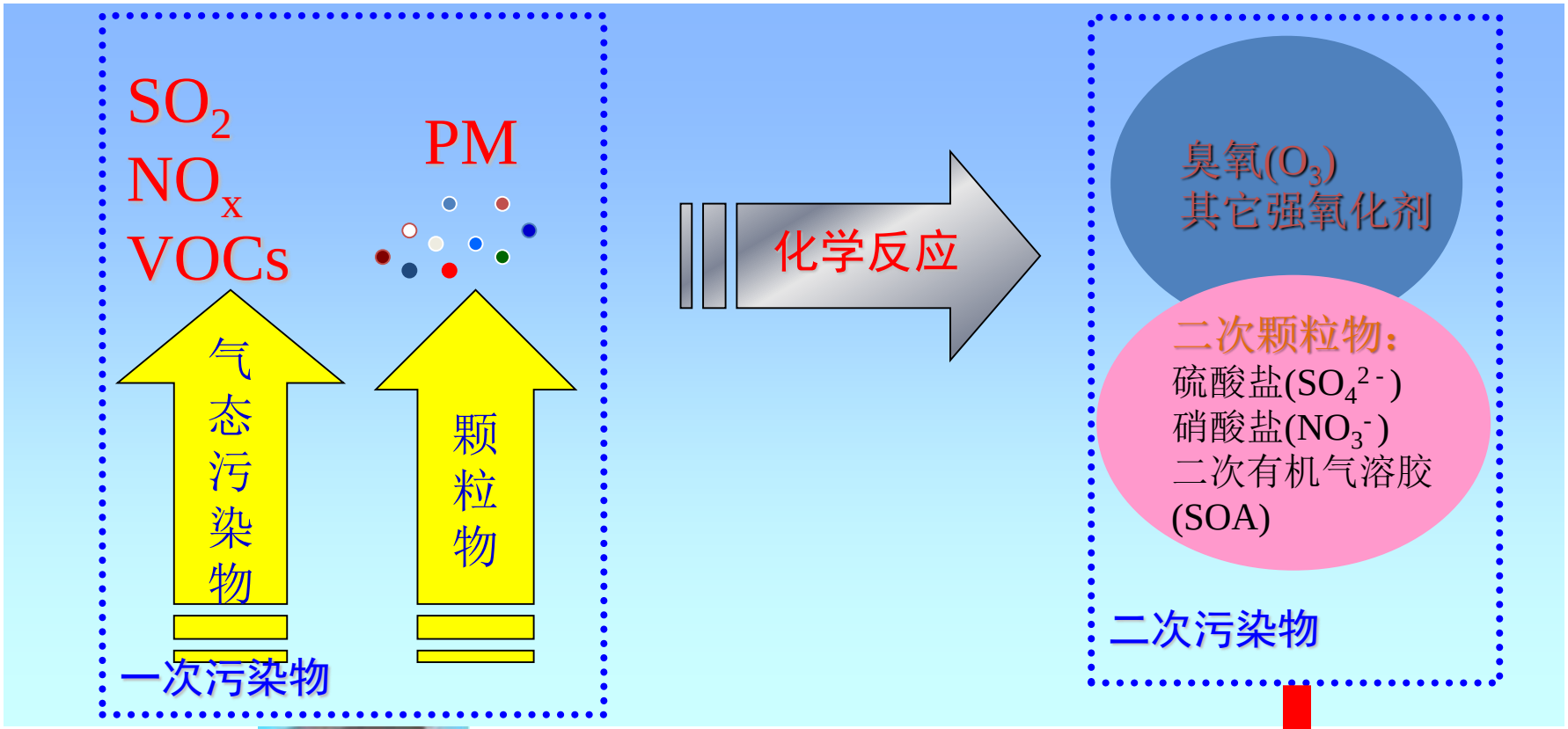


Today, exposure indoors to coal and biomass smoke affects more than 65% of the Chinese population, and about half of the world's population

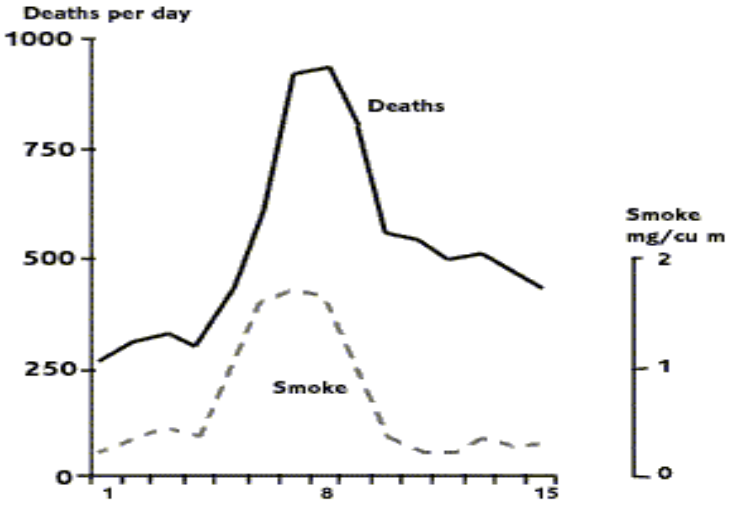
北京大学 PEKING UNIVERSITY

Air Pollution Formation in Cities

大气二次污染物经一次污染物通过复杂的非线性化学过程生成，是灰霾、光化学烟雾、酸雨的主要组分，其环境影响和控制原理与一次污染有很大的差异。



The Great London Smog of 1952



Death rate with concentrations of smoke

How happened?

1. Coal burning
2. Meteorological condition

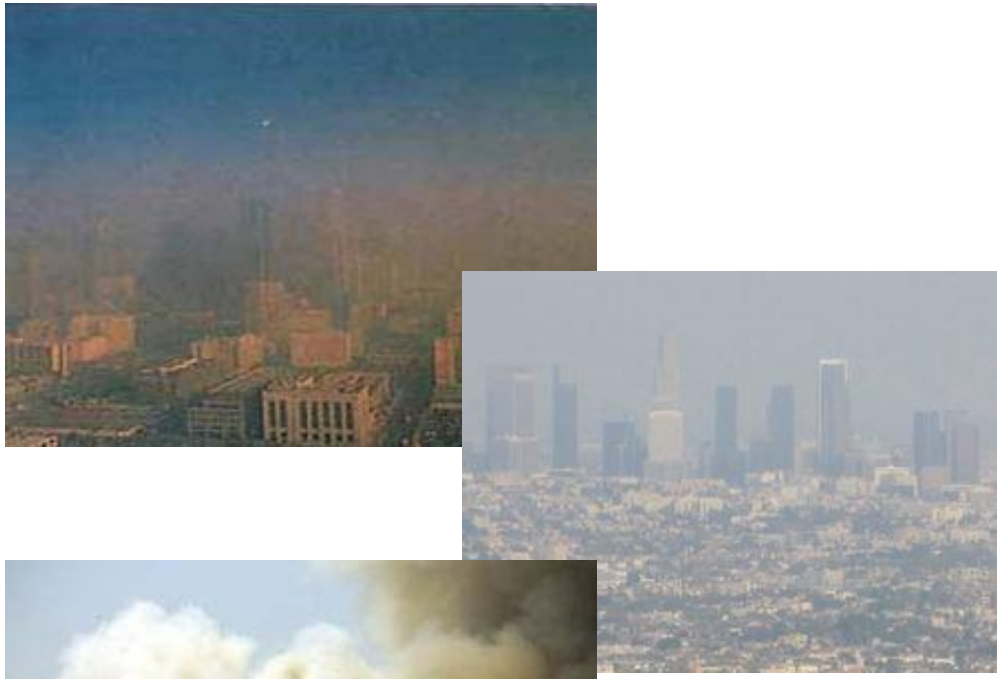
Primary pollutants

Carbon dioxide
Carbon monoxide
Sulfur dioxide
Dust…

Adverse health effects

5000 deaths of respiratory diseases in 5 days

Los Angeles, California, 1940's to 50's



How happened?

1. Vehicle and industrial emitted
2. Geographic factor
3. Meteorological condition

Photo-chemical reactions

$NO_2 + h\nu \rightarrow NO + O$

$O + O_2 \rightarrow O_3$

⋮

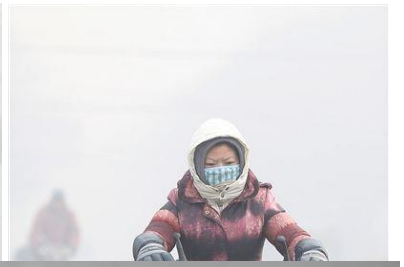
Adverse health effects

Eye irritation, throat pain
Respiratory difficulty, head pain, dizzy, etc…

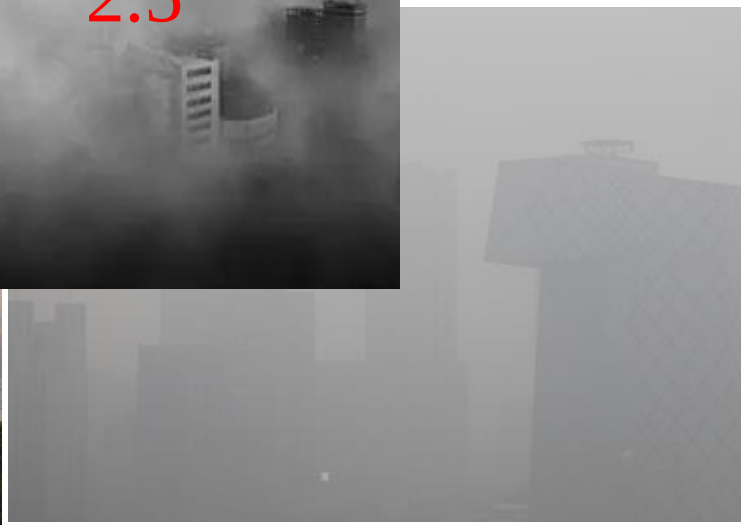
北京大学
PEKING UNIVERSITY

Content

1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）




柴静 中国雾霾调查-穹顶之下
PM2.5




©www.cfp.cn 版权作品 请勿转载

On Scale of 0 to 500, Beijing's $PM_{2.5}$ Tops 'Crazy Bad' at 755 μg/m³!!

Fashionably masked women on Saturday outside an amusement park in Beijing. The WHO has standards that judge an air-quality score above 500 to be more than 20 times the level of PM in the air deemed safe.

By Edward Wong
Published: January 12, 2013

The New York Times

WHO Air Quality Guidelines (2005)
Particulate matter – annual level

环境保护部《中国环境状况公报》公布的数据显示2015年全国338个地级以上城市中，仅有73个城市环境空气质量达标，占21.6%。超标天数中，以$PM_{2.5}$为首要污染物占得比例最高，达到66.8%，其次为臭氧和PM_{10}。京津冀及周边属空气重污染高发地区，2015年区域内70个地级以上城市共发生1710天次重度及以上污染，占2015年全国的44%，其中12月区域内连续发生多次大范围重污染过程，重度及以上污染发生天数占全年的36.8%。

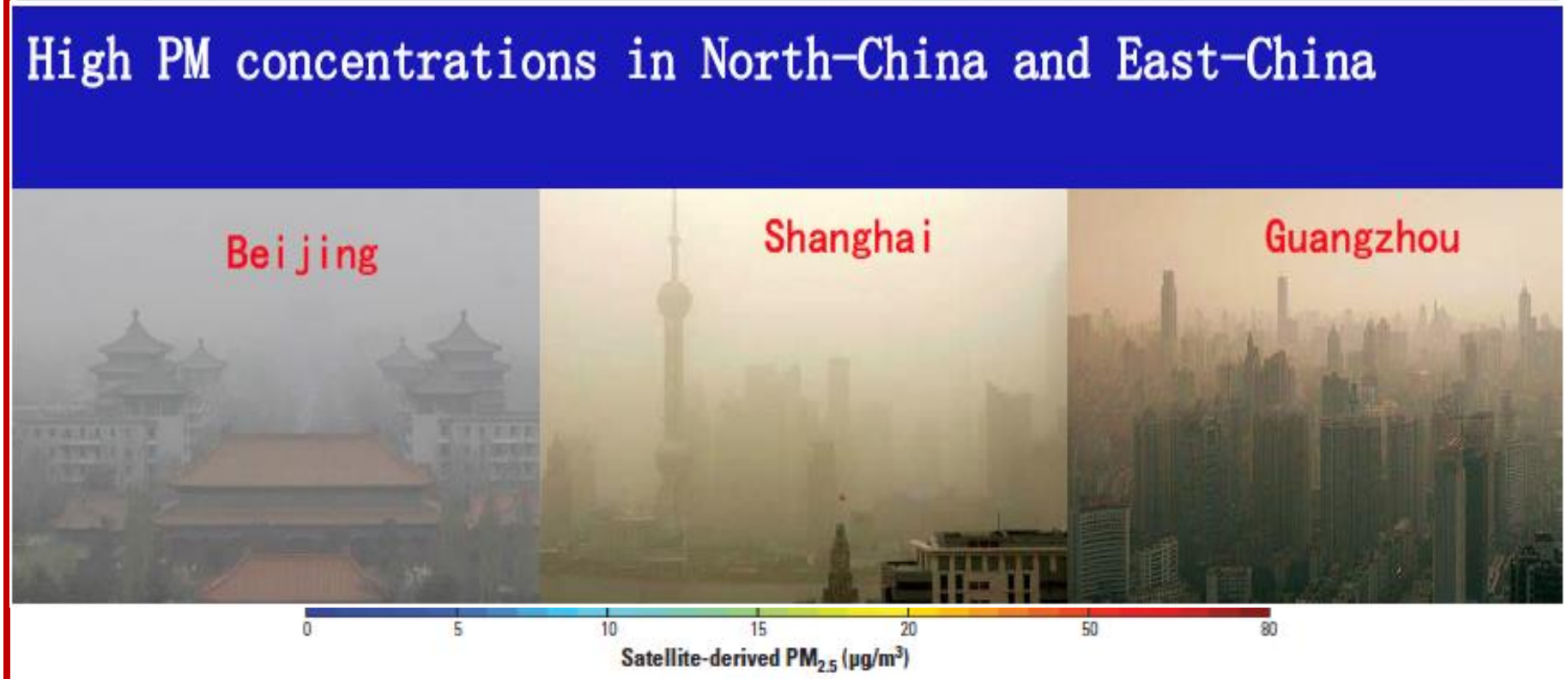
Standard			
WHO in			-term
WHO in			)-IT1
WHO in			2-11%]]
WHO Ai			rtality .5
Chin			
US EPA Air Quality Standards	/	**12, 35**	

‘Dirty' Energy Dwarfs Clean in China and India

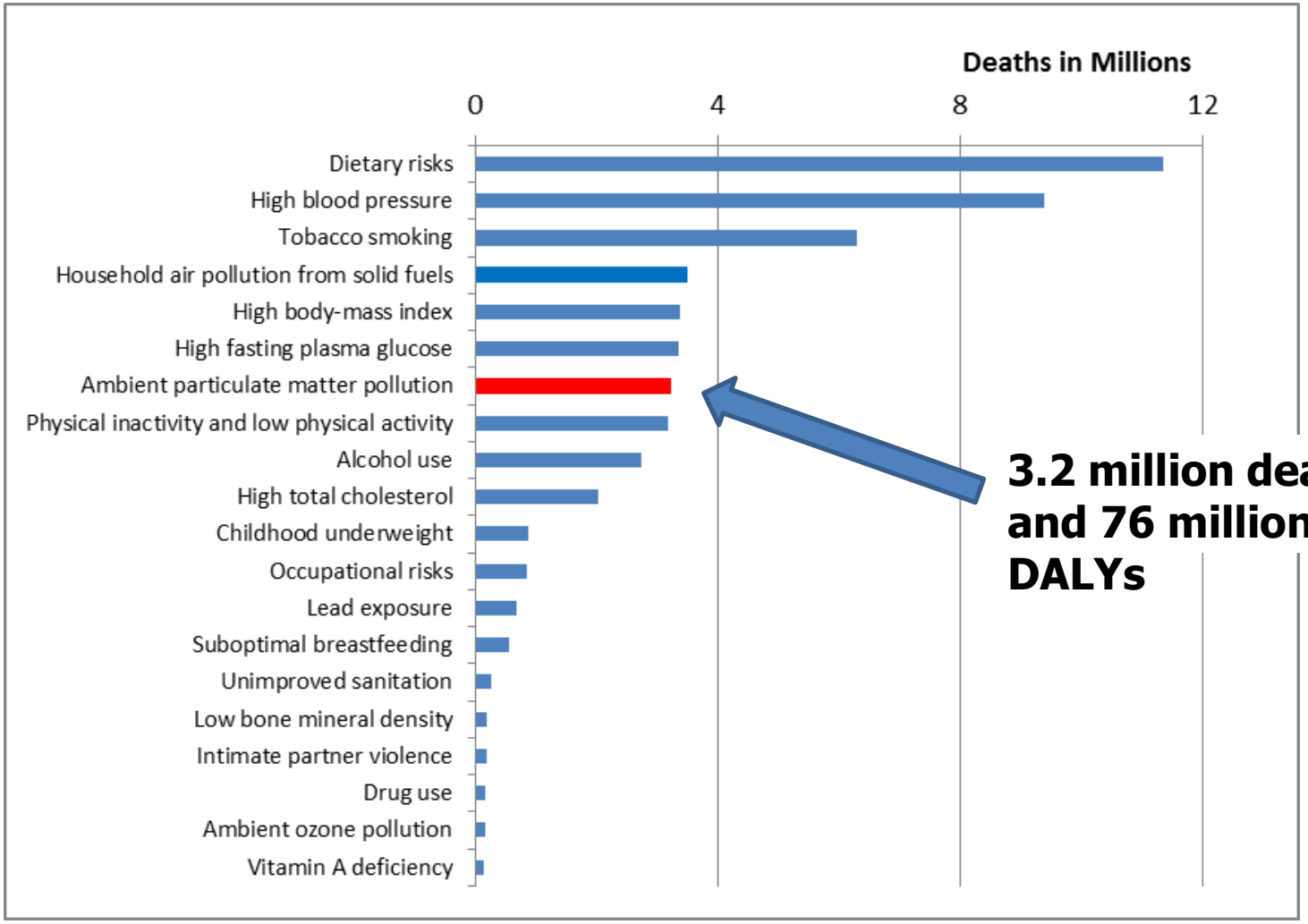
NY Times, February 21, 2011

By ELISABETH ROSENTHAL Reuters Smoke billows from a coal-burning power station in Beijing.

Global distribution of $PM_{2.5}$ from 2001-2006

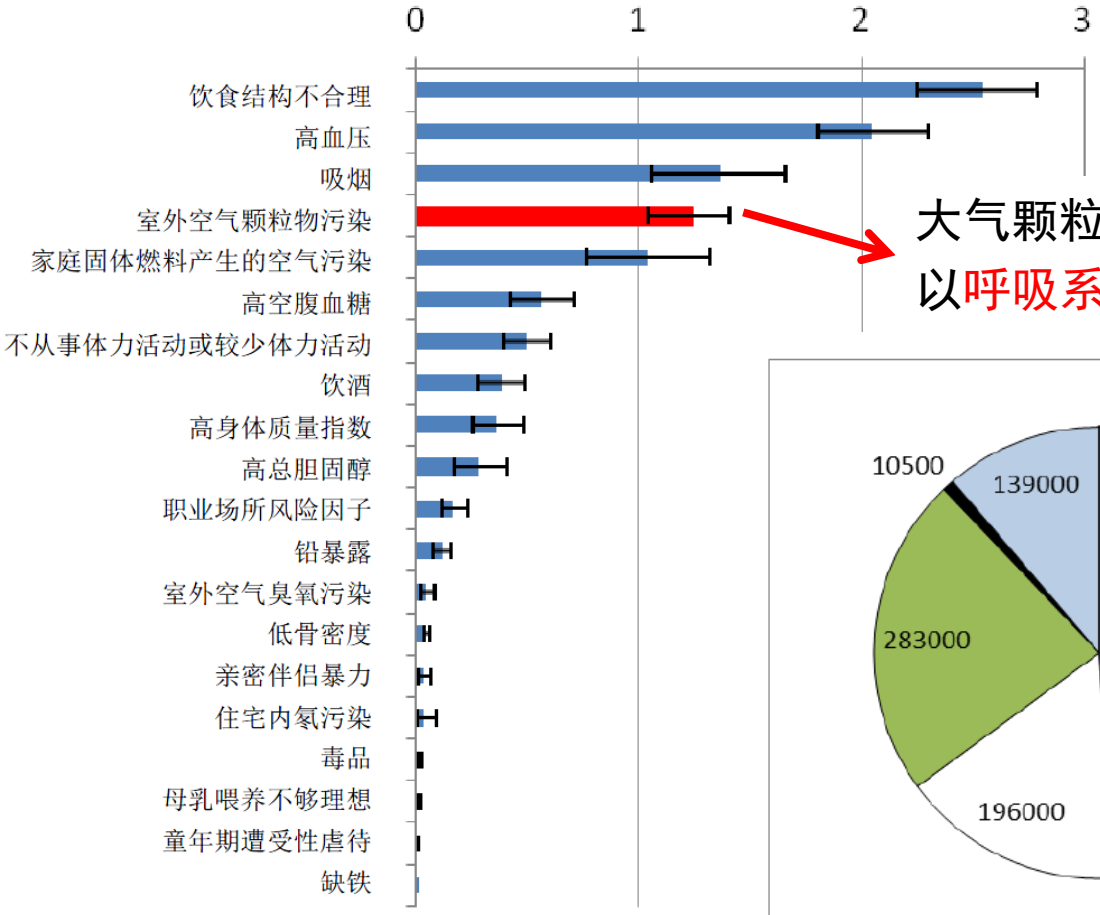


全球疾病负担2010 环境$PM_{2.5}$成为主要的死亡因素之一



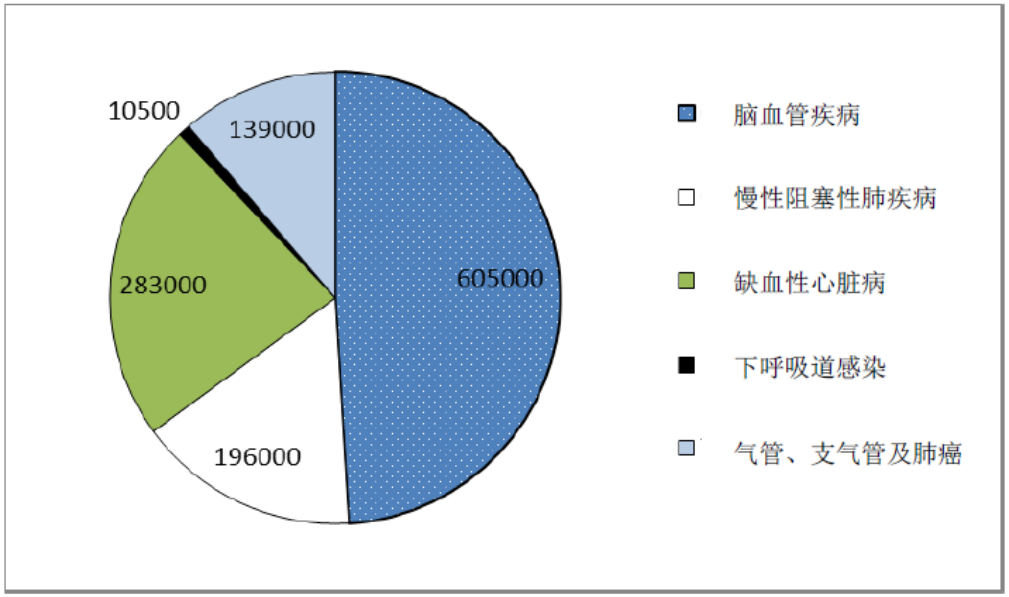
（Global Burden of Disease Study, Lancet, 2012）

2010年中国20个首要致死风险因子（死亡人数，单位：百万）



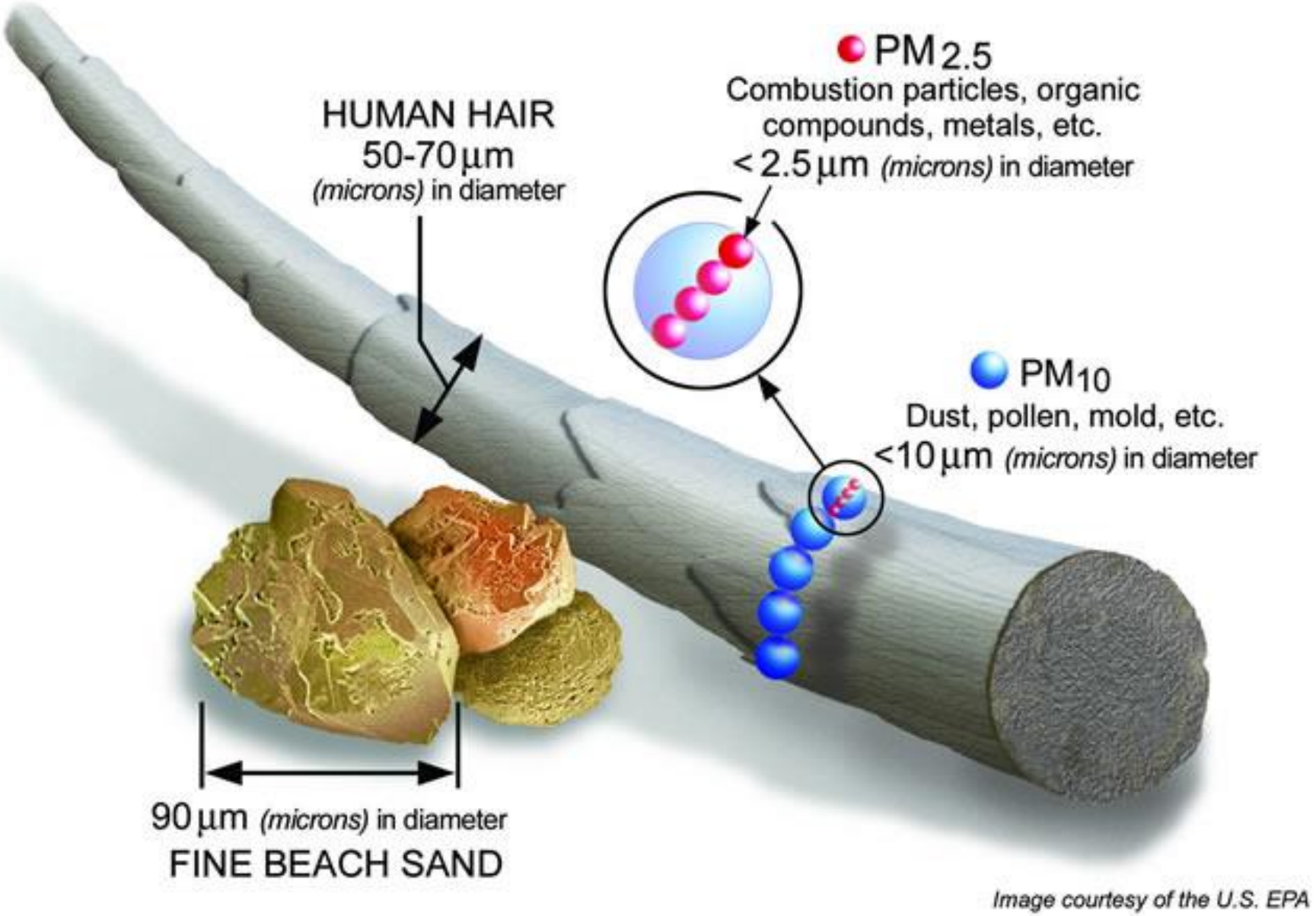
大气颗粒物污染导致死亡人数：123万

以呼吸系统和心脑血管疾病为主

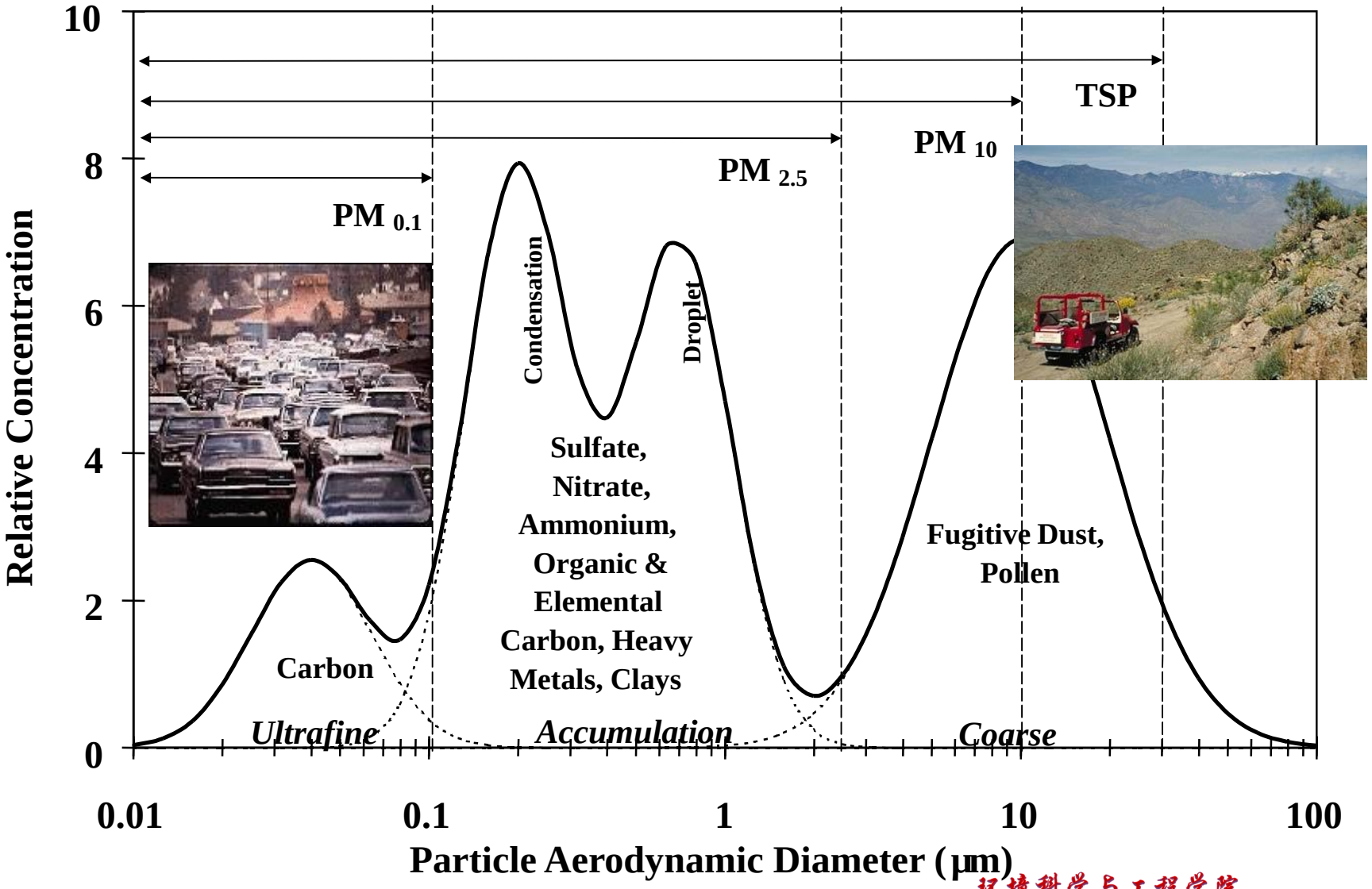


（Global Burden of Disease Study, Lancet, 2012）

大气细颗粒：小粒子，大问题 Small Particle, Big Problem

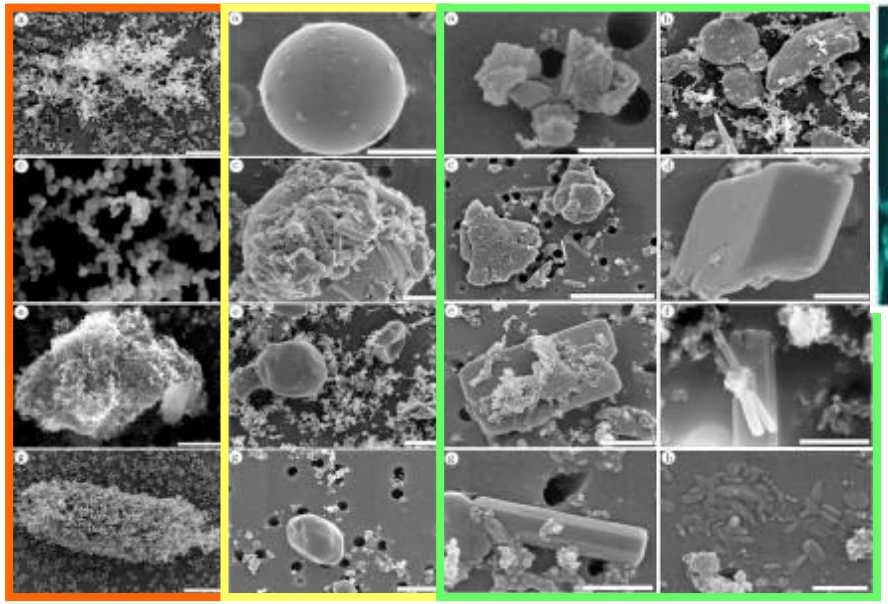


大气细颗粒物来源、粒径分布、成份结构复杂：包含非生物和生物组分



大气细颗粒物成份复杂：包含非生物和生物组分

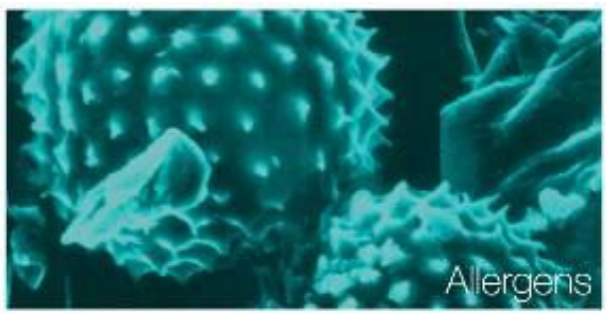
非生物

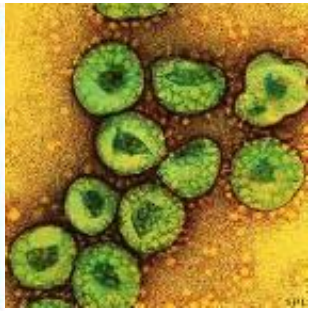


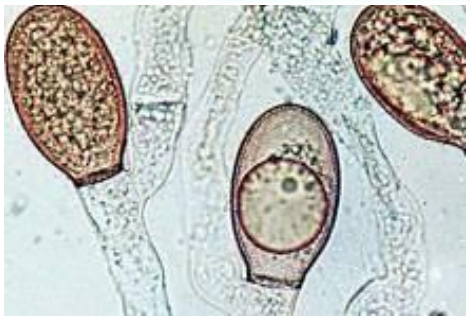
烟尘集合体、燃煤飞灰(coal fly ash)、矿物颗粒(邵龙义）

硫酸盐、硝酸盐、铵盐、金属、矿物质、有机物、黑碳

生物





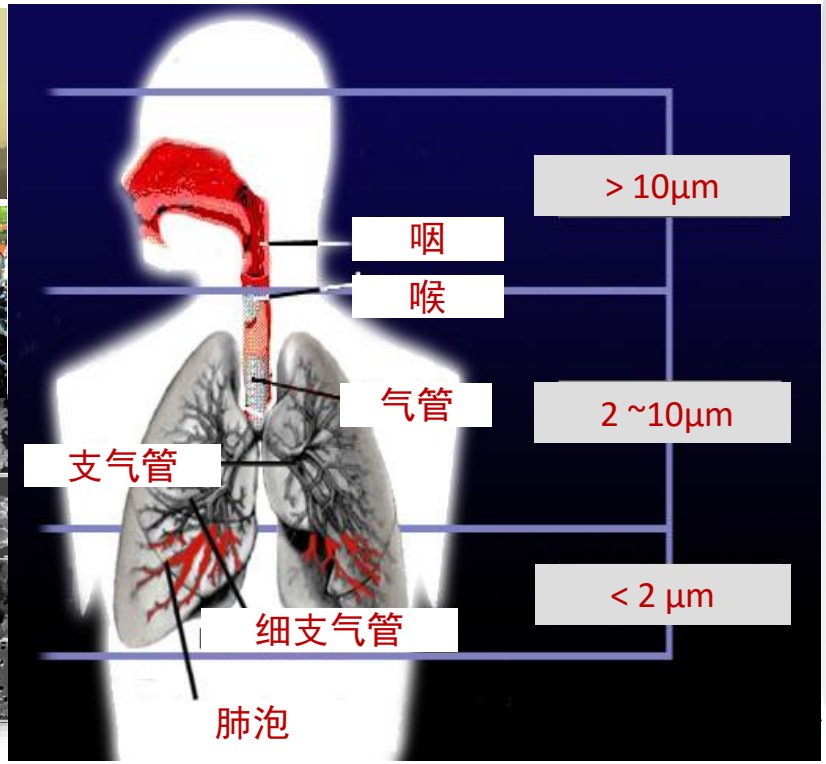


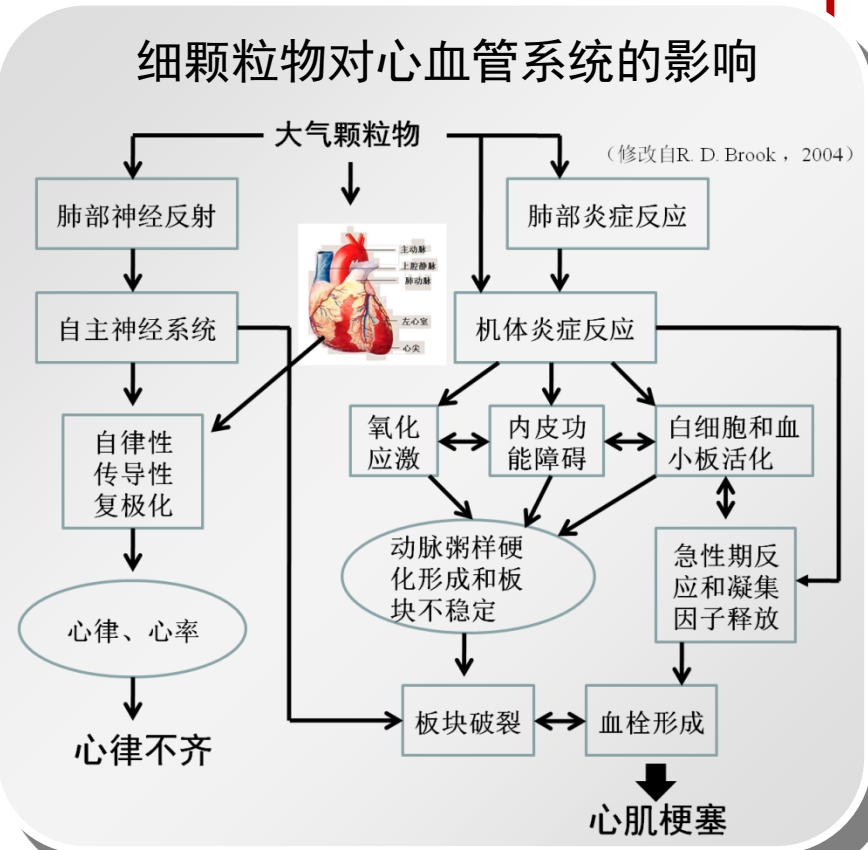
病毒、细菌、真菌、花粉

大气细颗粒危害人体健康、机制复杂

—大气中粒径小于2.5微米($PM_{2.5}$)的颗粒物

- 细颗粒来源与化学组份复杂，粒径越小的颗粒物，越能够沉积到呼吸道的深处，甚至进入血液循环系统，细颗粒暴露导致呼吸和心血管系统的发病率和死亡率增加。
- 细颗粒可诱发氧化性损伤，影响呼吸系统、心血管系统、免疫系统、生育系统、神经系统、遗传系统，但机制非常复杂，很多影响和机制尚不清楚。



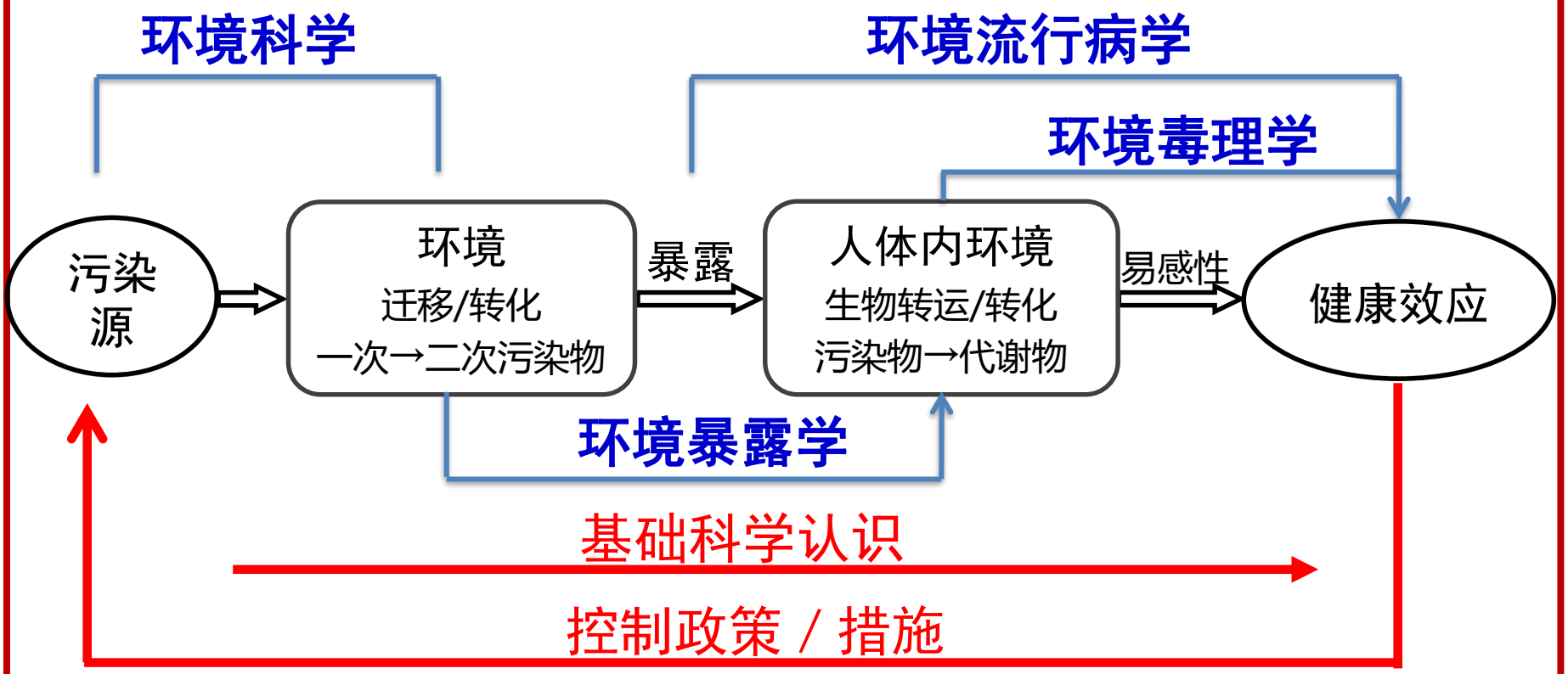


北京大学
PEKING UNIVERSITY

Content

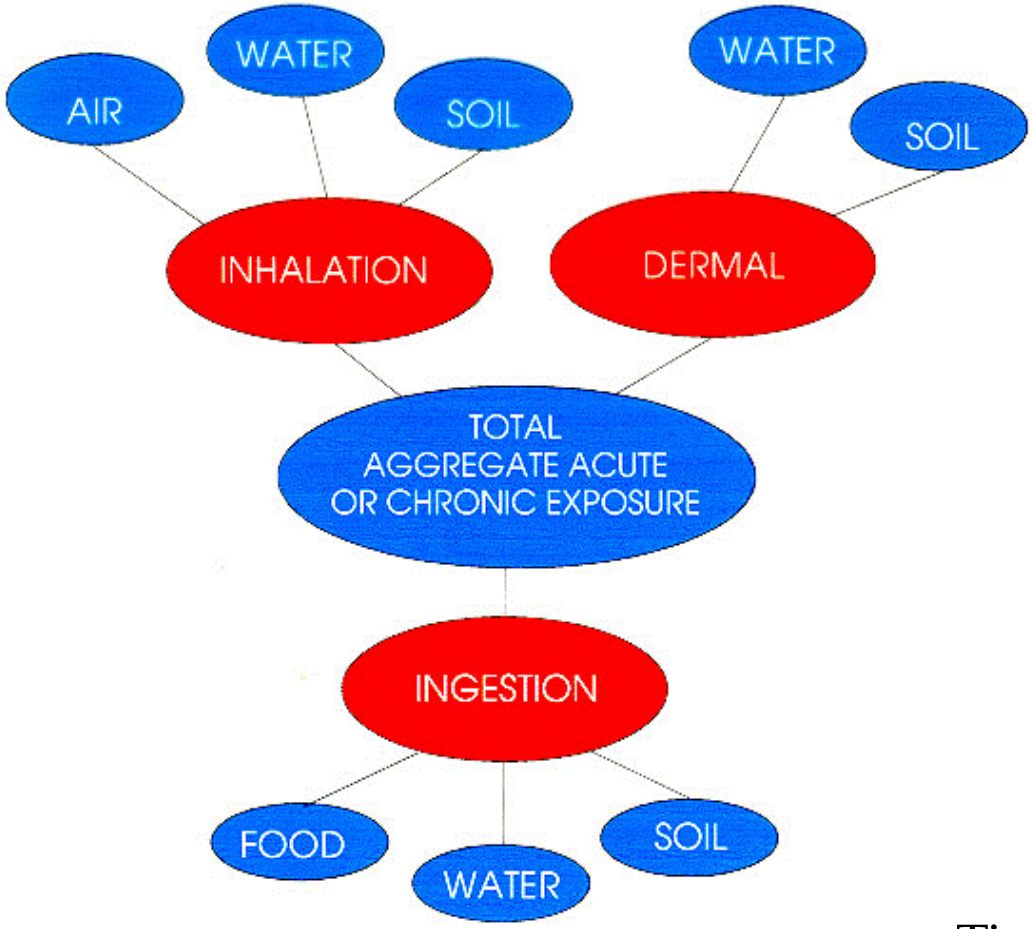
1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）

环境健康研究方法



环境与健康

NATURAL AND ANTHROPOGENIC SOURCES AND TRANSFERRED PRODUCTS



Tina (Zhihua) Fan
环境科学与工程学院
College of Environmental Sciences and Engineering

个体采样包
Sampling Pack

北京大学 Peking University

Personal Exposure Assessment

Filter Sampler： **Chemical Component**

Filter： 37mm Quartz

- Organic Components：EC/OC, PAHs, Cotinine, etc…

Exposure： 24h

- $PM_{2.5}$ Cyclone
- Flow Rate：4L/min
- Weight：453g
- 电量
- 降噪处理

BC personal sampler:

- Magee
- Time resolution: 1 min

北京大学 Peking University

Stationary Air Pollution Observatory at Peking University

Instruments	Analysis items	Size
SJAC*	Aerosol: SO_4^{2-}, NO_3^-, Cl^-, NO_2^-, NH_4^+	$PM_{1.0}$ or
	Gas: HCl, HNO_2, HNO_3, SO_2, NH_3	$PM_{2.5}$
TDMPS*	Size distribution of number, surface and	3 nm-10μm
APS*	volume concentrations	
HTDMA$^+$	Hygroscopic property	50 nm
		150 nm
Nox, O_3, SO_2*	NOx, O_3, SO_2	
MOUDI (10 stages)$^+$	EC/OC, Water soluble ions	56nm-18μm
Nano-MOUDI (3 stages)$^+$		10-56nm
Meteorological data^	T, RH, WS, WD, P	
TEOM1400a^	Mass concentration	PM_{10} or
		$PM_{2.5}$

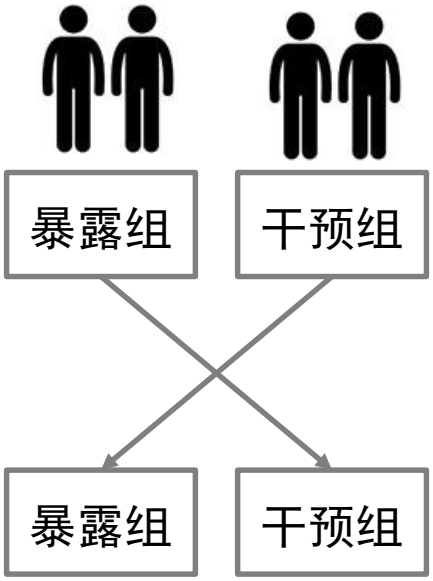
* Continuous measurements + Intensive measurements

^Cooperated with Department of Atmospherics Sciences, College of Physics

Environmental Epidemiology Study

实验性研究 → 观察性研究

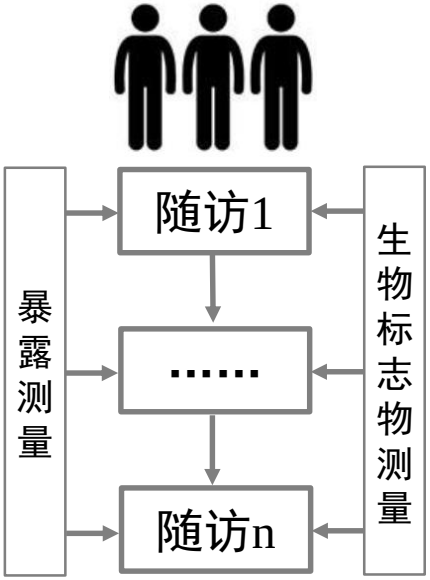
1.暴露干预实验



特点：随机-三盲-交叉设计（严格控制干扰因素）

目标：识别对健康有显著影响的环境暴露因素

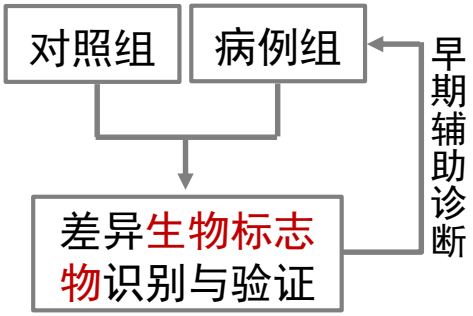
2.队列/定组研究



特点：实际环境暴露，自身对照以控制干扰因素

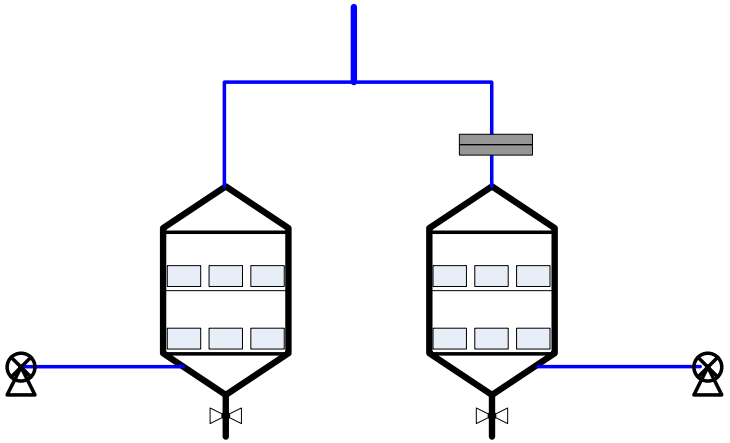
目标：建立暴露和效应的剂效关系

3.病例-对照研究



4.多中心定组人群研究

Environmental Control Facility



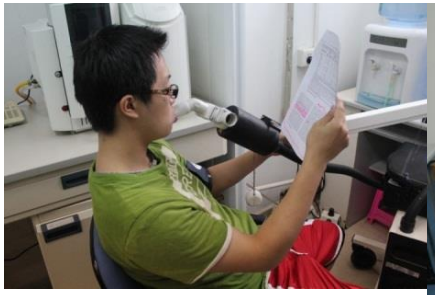
实验组：直接暴露于大气颗粒物
对照组：颗粒物过滤

Peking Uni-Shenzhen
Exposure Chamber

志愿者完成2小时暴露

实验前佩戴动态心电、血压监测仪

完成暴露后，重复采集呼出气及呼出气冷凝液、尿液



Content

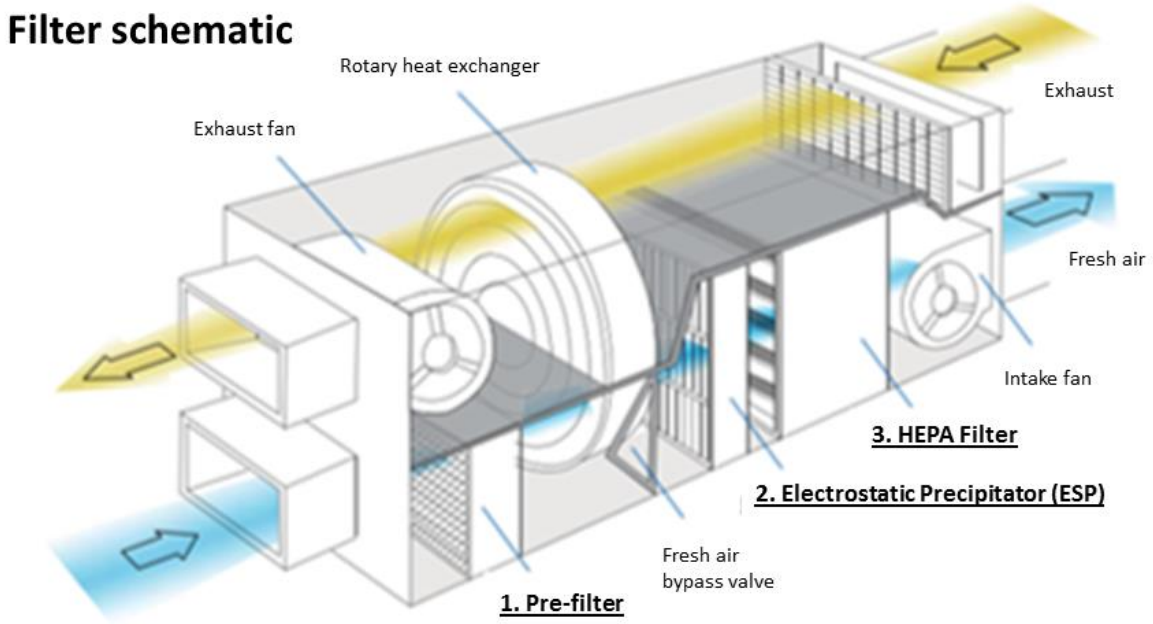
1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）

Broad Town

http://en.broad.com/News-1.aspx

Courtesy from Dr. Drew Day

Central AHU Filtration Schematic



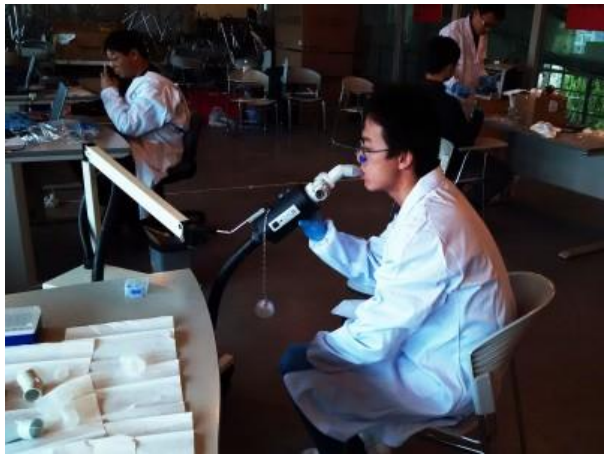
Courtesy from Dr. Drew Day

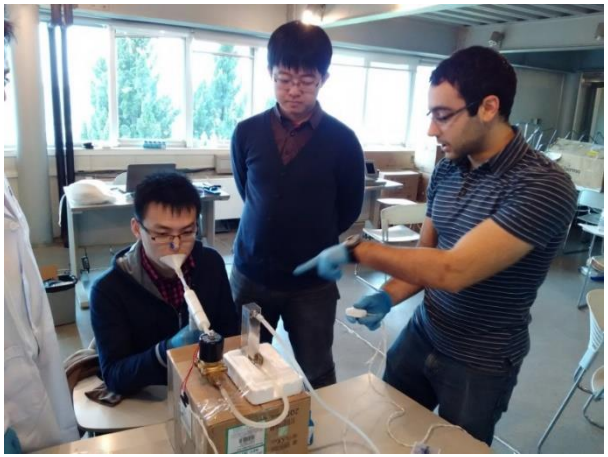
Study Design

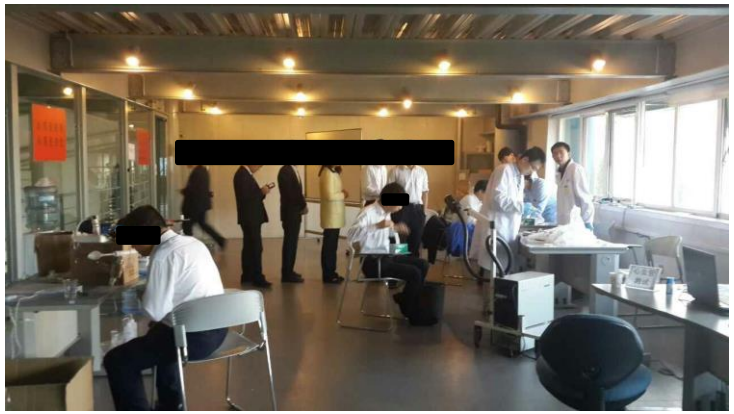
Condition	Pre-intervention (Dec. 1-5, 2014)	Intervention (Dec. 6, 2014 – Jan. 13, 2015)	Post-intervention (Jan. 14-31, 2015)
Duration	5 days	39 days	18 days
Biomarker sampling visits	Visit 1 (Dec. 2-5, 2014)	Visit 2 (Dec. 23-26 & 30, 2014) & Visit 3 (Jan. 6-8 & 13, 2015)	Visit 4 (Jan. 27-30, 2015)
Group A			
Filtration	F8 + ESP + HEPA	F8	F8 + ESP + HEPA
Office Location	Office A	Office A	Office A
Living Quarters	Dorm Buildings 1-6	Dorm 4A (Hotel)	Dorm 4A (Hotel)
Group B			
Filtration	F8 + ESP + HEPA	F8 + HEPA	F8 + ESP + HEPA
Office Location	Office B	Office B	Office B
Living Quarters	Dorm Buildings 1-6	Dorm Buildings 1-6	Dorm Buildings 1-6

Courtesy from Dr. Drew Day

Biomarker Collection in the Field





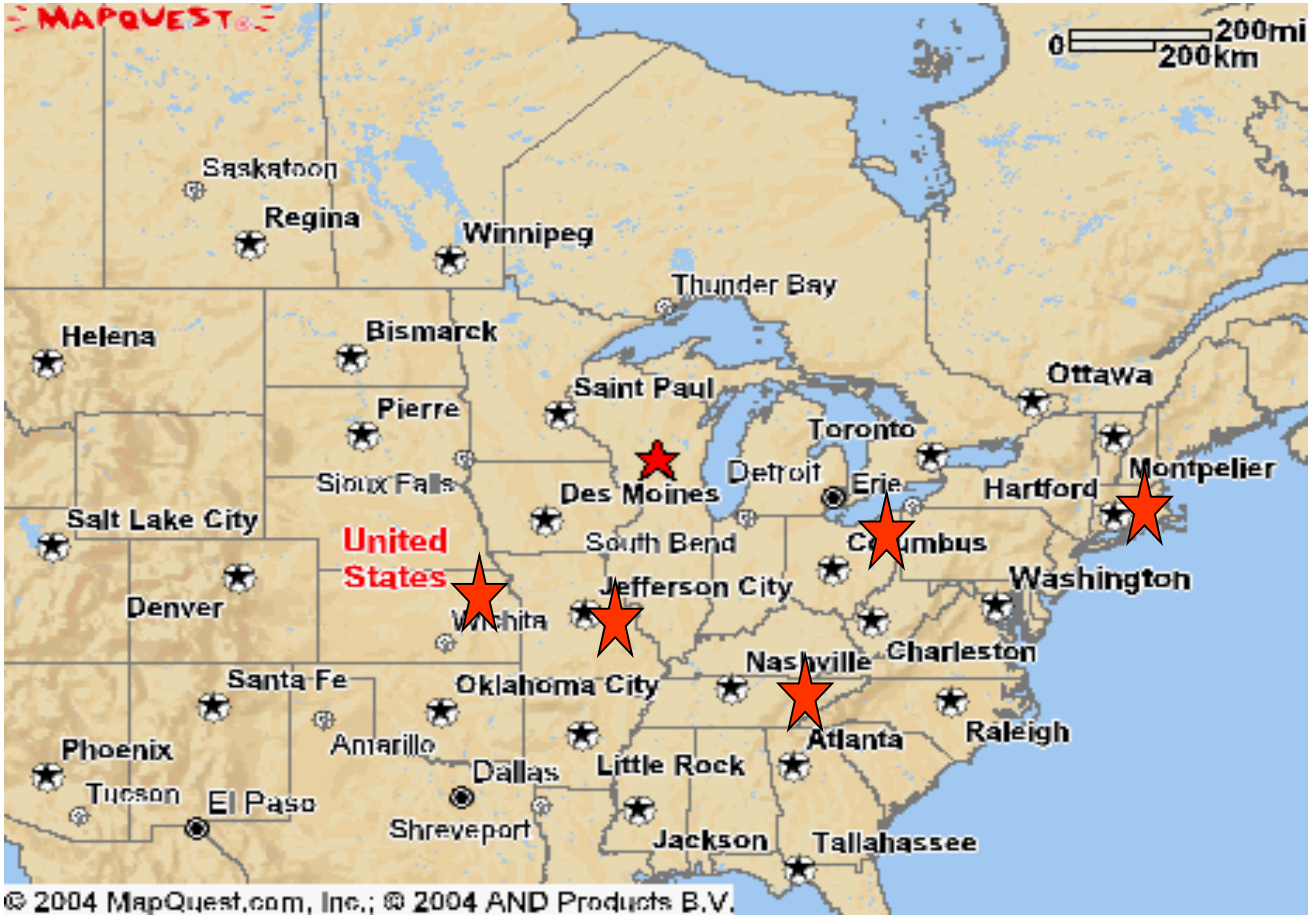


Courtesy from Dr. Drew Day

Principal Findings

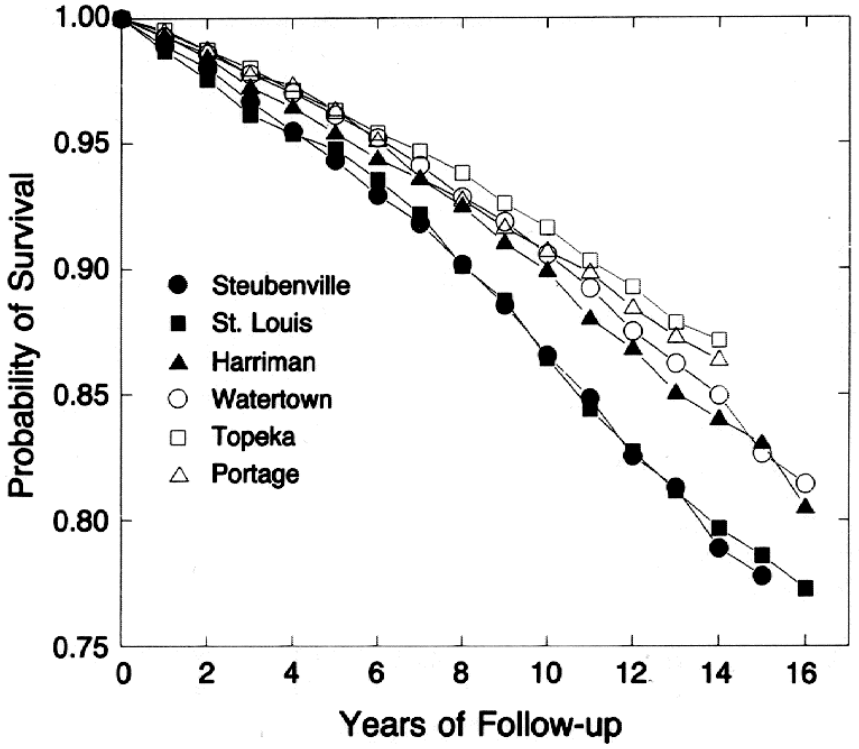
- O_3 was associated with sCD62P (platelet activation) and DBP (blood pressure)
- O_3 not associated with lung function changes
- $PM_{2.5}$ and SO_2 weakly positively associated with VWF (endothelial dysfunction) and AI (arterial stiffness)

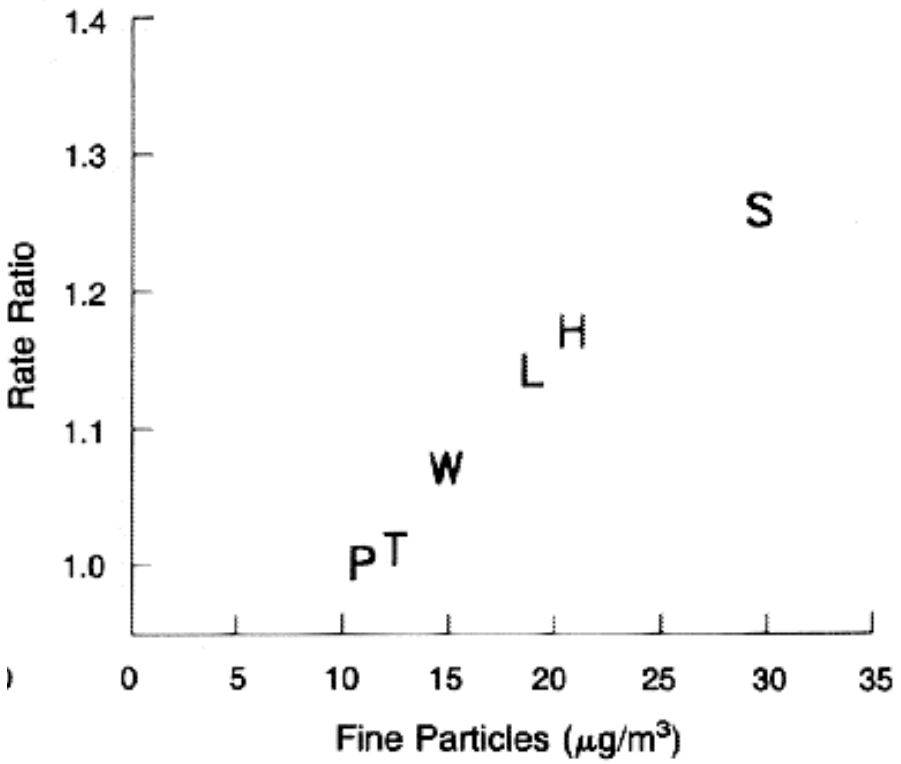
Harvard Six Cities Cohort Study



- ~9,000 subjects living in 6 U.S. cities
- Followed for 15 years
- Cities varied in long-term concentrations of sulfur oxides and particles

Harvard Six Cities Cohort Study



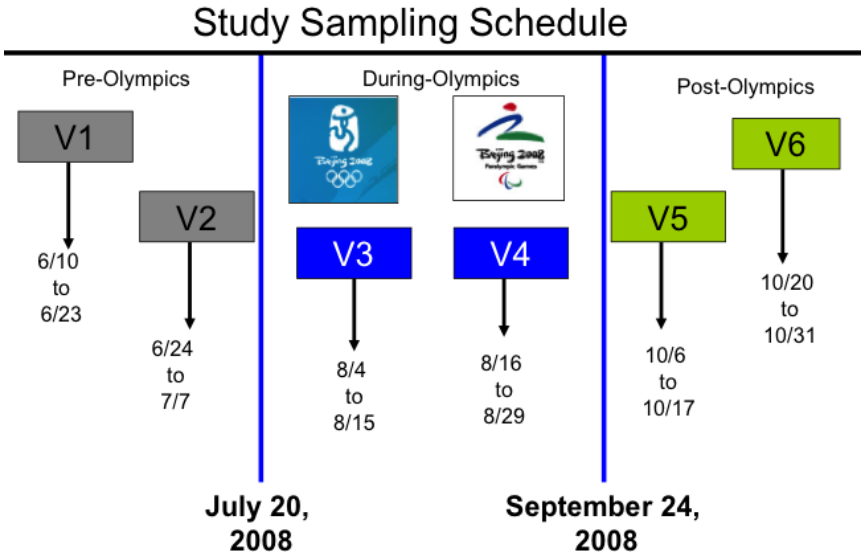


Dockery, NEJM 1993; 329: 1753-9

北京大学 PEKING UNIVERSITY

Beijing Olympic Panel study

- Whether the drastic changes in air pollution induce adverse health effects on cardio-respiratory system?
- Is this effect reversible?



Air Pollutants

$PM_{2.5}$, EC, OC, SO_4, SO_2, NO_2 CO

Pulmonary

(Inflammation & Oxidative stress)

FeNO

EBC: pH, Nitrite and nitrate, MDA

Autonomic function

SBP, DBP, Heart rate

HRVs: HF, LF, LF/HF, VLF, rMSSD, SDNN, total power

Hemostasis

sCD62P, sCD40L, VWF, platelet activation

Systemic

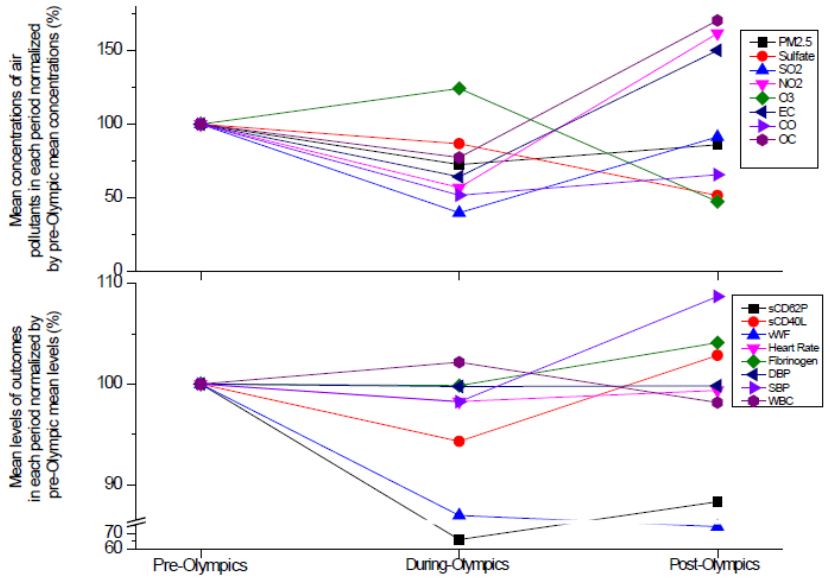
(Inflammation & Oxidative stress)

8-OHdG, MDA, Fibrinogen, WBC, RBC, lymphocyte, neutrophil, CRP, 8-isoprostane

北京大学 Peking University

Beijing Olympic Panel study

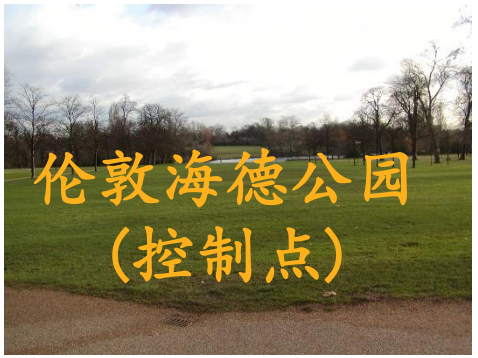
利用北京奥运空气质量控制的时机开展**定组**研究HEART，发现空气质量改善的同时人体炎症/血栓/氧化应激等**生物标志物**均显著改善，从而**获得细颗粒物早期健康效应的直接证据**。



(Rich…..Zhu*, Zhang* *JAMA, 2012*)

不同易感性人群对大气污染物暴露的健康响应

具有不同易感性的人群对柴油机尾气暴露的健康响应是否不同？



- 选取三组不同易感性人群各40人
  - 健康人群
  - 慢性阻塞性肺部疾病患者
  - 缺血性心脏病患者
- 暴露方法
  - 暴露点和对照点
  - 暴露时间2小时
- 暴露污染物测量
  - 在线测量
  - 细颗粒物、超细颗粒物、NO_2、黑炭、噪音等
- 健康指标的测量
  - 暴露前2小时
  - 暴露中
  - 暴露后0-24小时

Time re. exposure	-2hr	0hr	+1hr	+2hr	+3hr	+4hr	+5hr	+6hr	+24h
Place	lab	site	site	site	lab	lab	lab	lab	lab
Symptoms	X	X		X		X		X	X
Arterial stiffness(Vicorder)	X				X		X	X	X
FeNO	X				X		X		X
ST segment ECG	X								
Venesection	X							X	X
Urine collection	X								X
Spirometry	X	X	X	X	X		X	X	X
Impulse oscillometry	X					X			X
Breath condensate	X					X			X
Induced sputum									X

北京大学 PEKING UNIVERSITY

不同易感性人群对大气污染物暴露的健康响应

Results 1: Volunteer characteristics (mean and range)

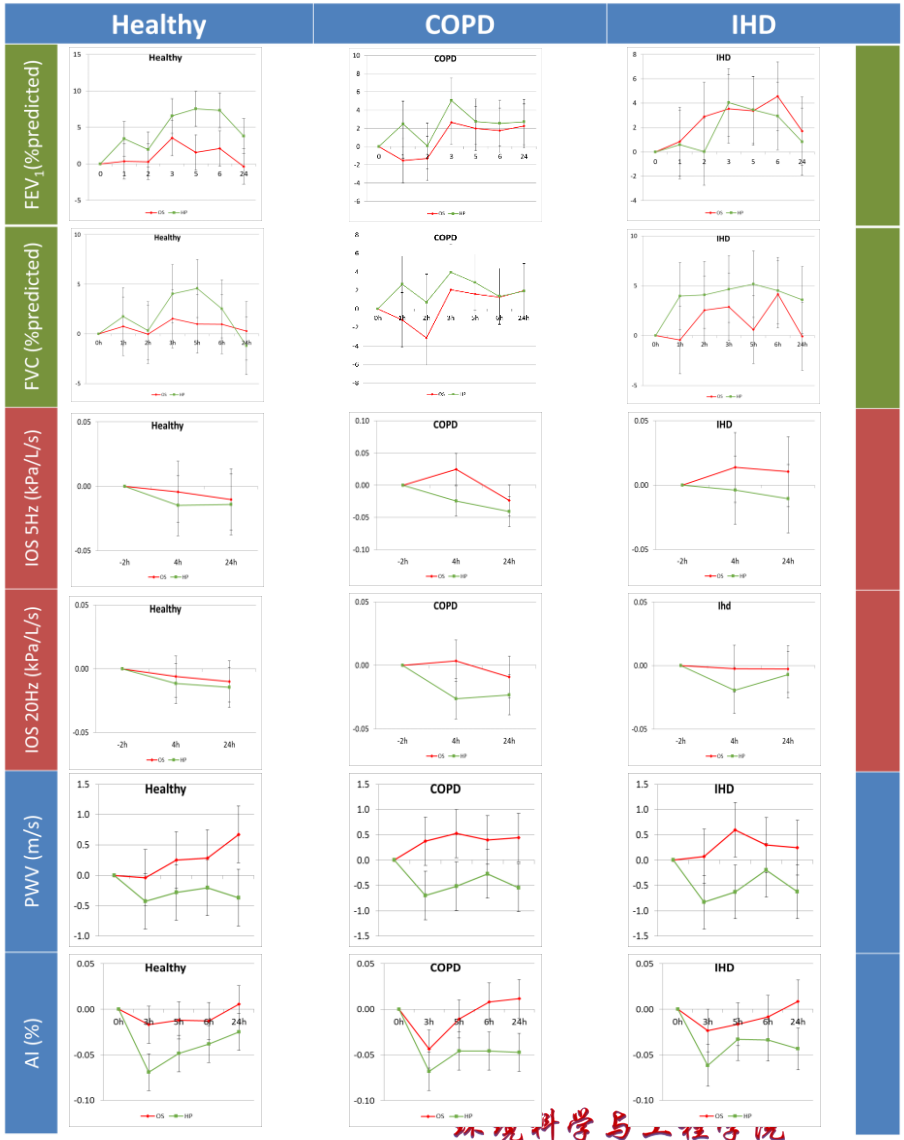
Group	Male/ Female	Age	FEV1 % pred	FVC % pred	PWV m/s	AI %	IOS 5Hz kPa/L/s	IOS 20Hz kPa/L/s
Healthy (n=40)	19/21	62 (46, 76)	98 (52, 141)	106 (56, 156)	8.3 (4.5, 17.7)	25 (9, 52)	0.40 (0.20, 1.06)	0.34 (0.18, 0.89)
COPD (n=40)	19/21	68 (49, 83)	58 (15, 112)	88 (42, 157)	9.3 (5.9, 14.4)	26 (7, 65)	0.57 (0.30, 1.32)	0.38 (0.19, 0.79)
IHD (n=39)	35/4	67 (45, 88)	97 (41, 141)	100 (43, 161)	9.4 (4.2, 30.0)	25 (4, 47)	0.47 (0.26, 1.86)	0.36 (0.22, 0.76)

Results 2: Exposure comparison

Air pollutant	Hyde Park			Oxford Street			P values*
	N	mean	SD	N	mean	SD	
$PM_{2.5}$ (μg/m³)	83	10.7	12.6	82	18.9	10.3	0.0014
PM_{10} (μg/m³)	83	23.1	16.3	82	31.5	12.9	0.0095
PN (cm^{-3})	83	6264	2946	80	26031	8033	<0.0001
Carbon black (μg/m³)	80	1.0	0.7	83	6.9	2.6	<0.0001

*P values for the comparisons of the concentrations of each air pollutant between two locations

Results 3: Cardio-respiratory outcomes comparisons



初步结果

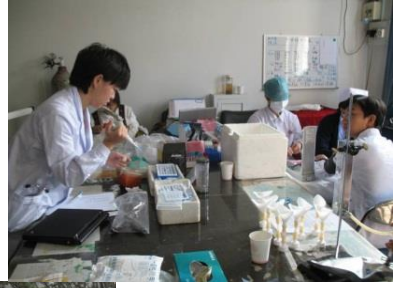
➢三组人群的肺部生理机能对大气污染物暴露响应有显著性差异，包括肺功能和呼吸道阻力。

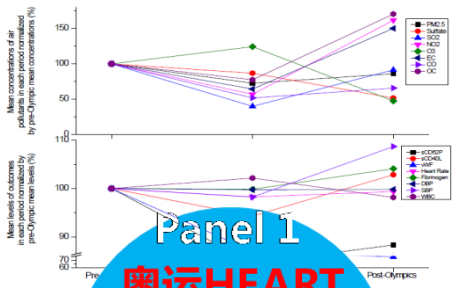
➢三组人群的动脉血管硬化指标都随着大气污染物暴露水平的增加而升高，但是响应的时间和强度不同。

[Gong et al., 2017, in preparation]

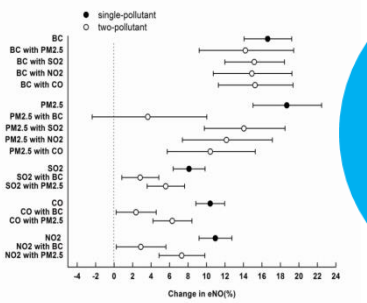
Content

1. 背景（Background）
2. 现状（Current Status）
3. 方法（Study methods）
4. 例证（Study examples）
5. 展望（Outlooks）

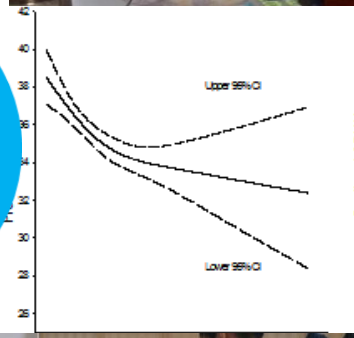




Panel 1
奥运HEART
健康青年
心肺功能
干预措施影响
(JAMA，2012)



Panel 2
儿童
呼吸系统炎症
氧化应激
(EHP，2011)

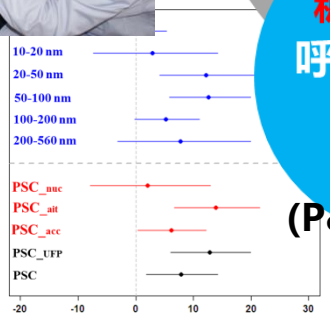


Panel 3
老年
心脏节律
系统炎症
(AJE，2012)

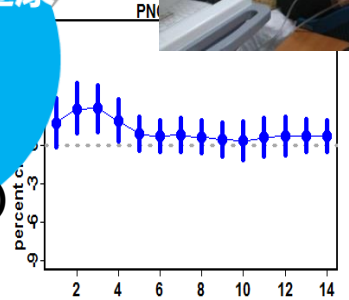
2004-今

形成了成熟的以生物标志物为基础的定组研究方法

Panel 4
糖尿病人群
呼吸系统炎症
心脏节律
粒径效应
(P&FT，2015)



Panel 5
糖尿病前期/健康
心肺系统
内皮功能
代谢指标
(On-going)



北京大学 Peking University

通过学科交叉形成系列研究成果

JAMA The Journal of the American Medical Association

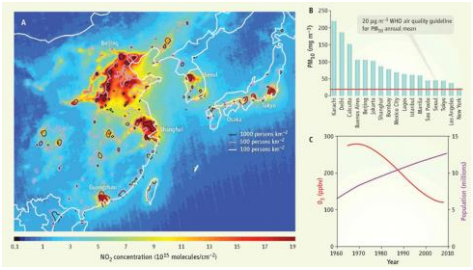
Association Between Changes in Air Pollution Levels During the Beijing Olympics and Biomarkers of Inflammation and Thrombosis in Healthy Young Adults FREE

David Q. Rich, ScD; Howard M. Kipen, MD, MPH; Wei Huang, ScD; Guangfa Wang, MD; Yuedan Wang, PhD; Ping Zhu, MD; Pamela Ohman-Strickland, PhD; Min Hu, PhD; Claire Philipp, MD; Scott R. Diehl, PhD; Shou-En Lu, PhD; Jian Tong, MS; Jicheng Gong, PhD; Duncan Thomas, PhD; Tong Zhu, PhD; Junfeng (Jim) Zhang, PhD

环境科学-基础/临床/预防医学

筛选生物标志物，确定北京奥运空气污染与炎症、血栓、心血管指标急性改变的关联

Science AAAS



CLIMATE CHANGE

Clean Air for Megacities

David D. Parrish[1] and Tong Zhu[2]

环境健康-气候学

指出了改善城市空气质量，以实现保护人体健康和应对气候变化的“共赢”途径。

PNAS

Association of selected persistent organic pollutants in the placenta with the risk of neural tube defects

Aiguo Ren[a,1,2], Xinghua Qiu[b,1], Lei Jin[a], Jin Ma[b], Zhiwen Li[a], Le Zhang[a], Huiping Zhu[c], Richard H. Finnell[c,d], and Tong Zhu[b,2]

[a]In
10
Ce
[d]D

Center, Beijing
neering and
l Sciences and

环境科学-生殖流行病学

发现胎盘中多环芳烃等污染物与神经管畸的发生风险相关，呈显著的剂量-反应关系

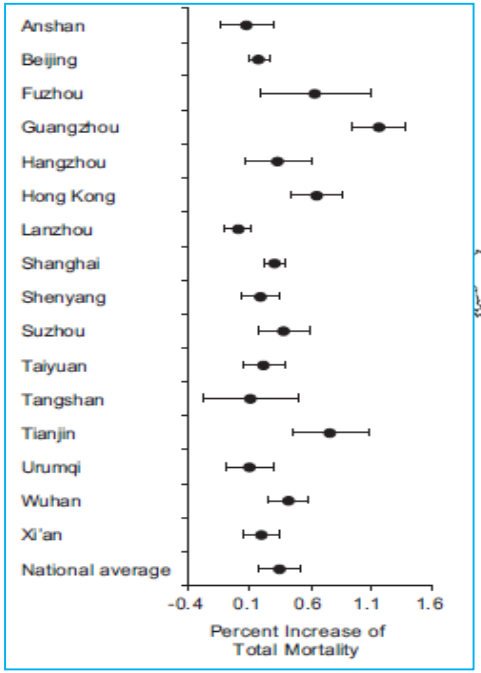
北京大学 Peking University

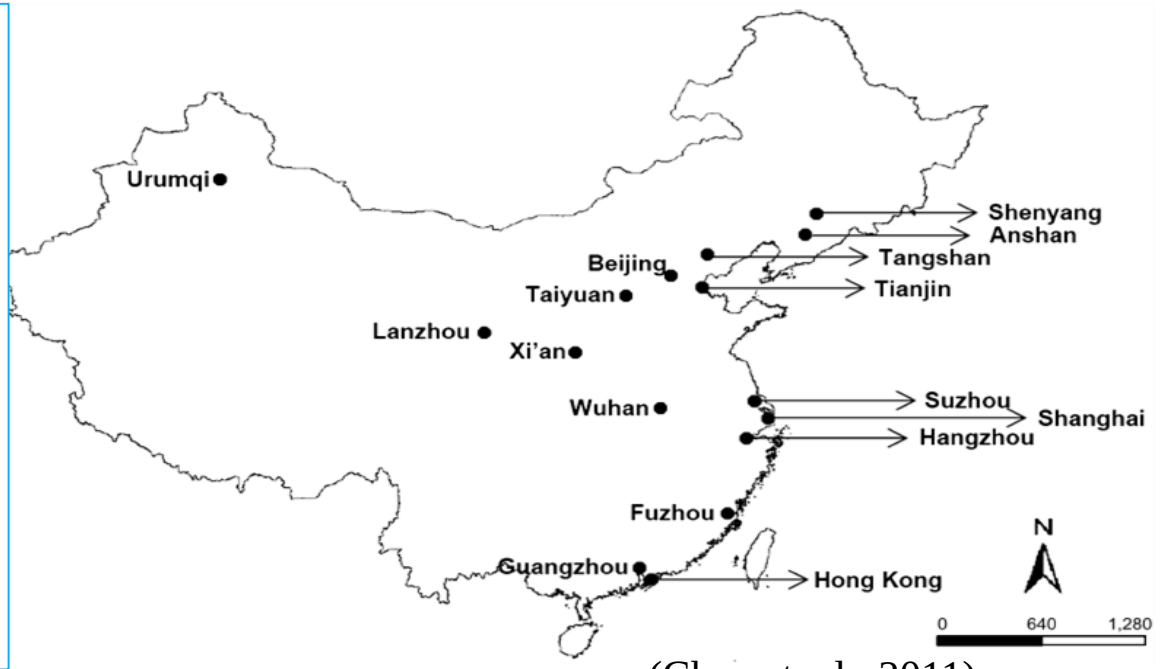
我国大气污染健康效应研究

我国一些大城市开展了时间序列和回顾性队列研究，验证了高污染下颗粒物质量浓度与心肺系统疾病死亡率之间的关联。但是这一类研究：

1. 无法揭示早期健康效应——涉及早期预防

2. 无法解释健康效应的机制及影响因素——涉及有效控制





(Chen et .al., 2011)

北京大学
Peking University

感谢大家对环境问题的关注！