

Managing and Improving Air Pollution

By
Dr David Carruthers
CERC

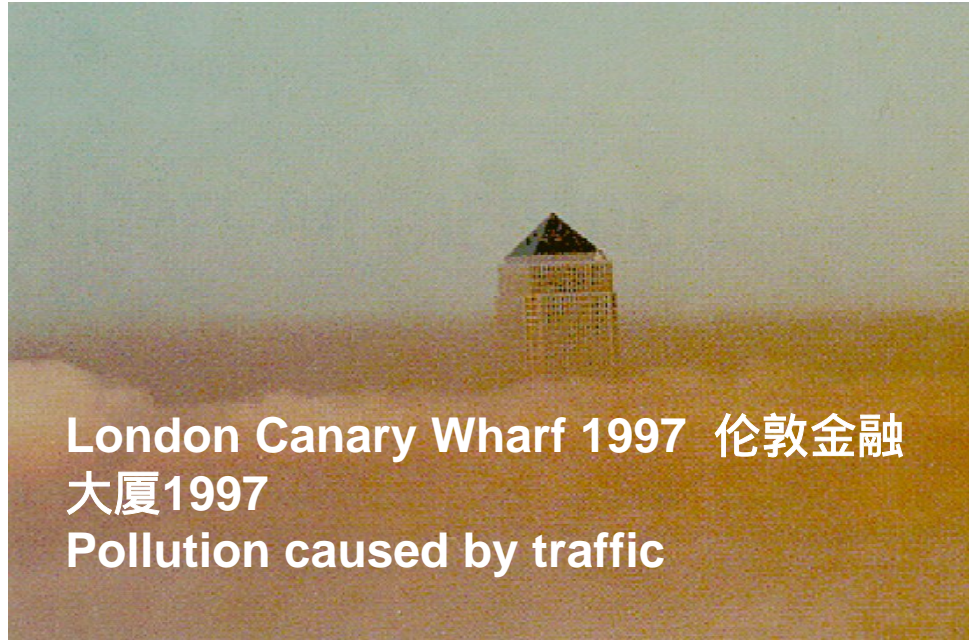
China Executive Learning Programme
Judge Business School, Cambridge
July 2009

Historical examples of air pollution in the UK CERC

London smog 1952
伦敦烟雾事件 1952
Coal burning –
industry and domestic



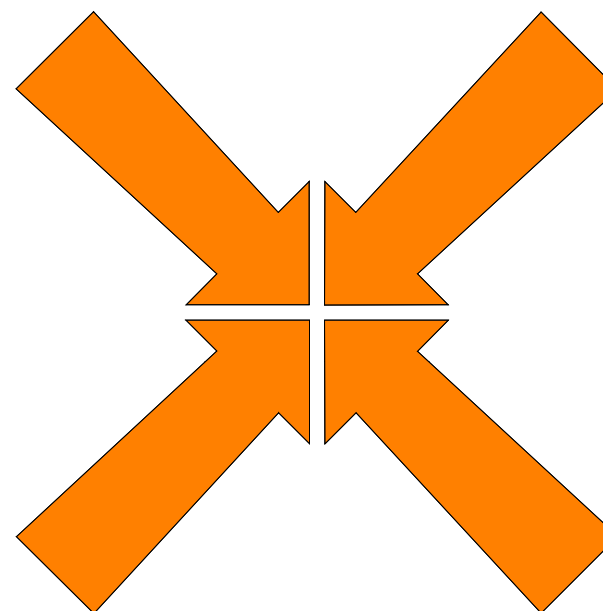
London Canary Wharf 1997 伦敦金融大厦1997
Pollution caused by traffic



Air Quality in UK now usually good

CAFÉ POLICY INTEGRATION

- Ambient air quality
- Industry emissions
- Vehicle/fuel standards
- National ceilings
- Consider cost effectiveness



**Air Quality in Europe is much improved and is generally good
– still some pollution episodes**

Chang An Avenue, Beijing, in 1979 长安街

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Pollution sources in China

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Industrial Sources 工业污染源
Inner Mongolia

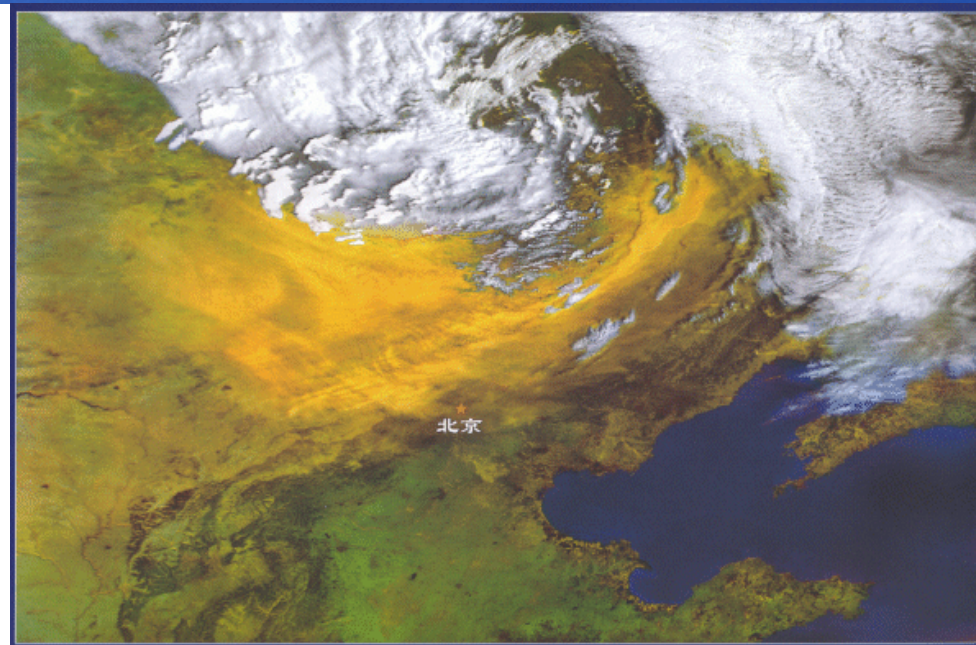


Traffic in Modern Beijing
现代北京的交通

Regional Pollution in China

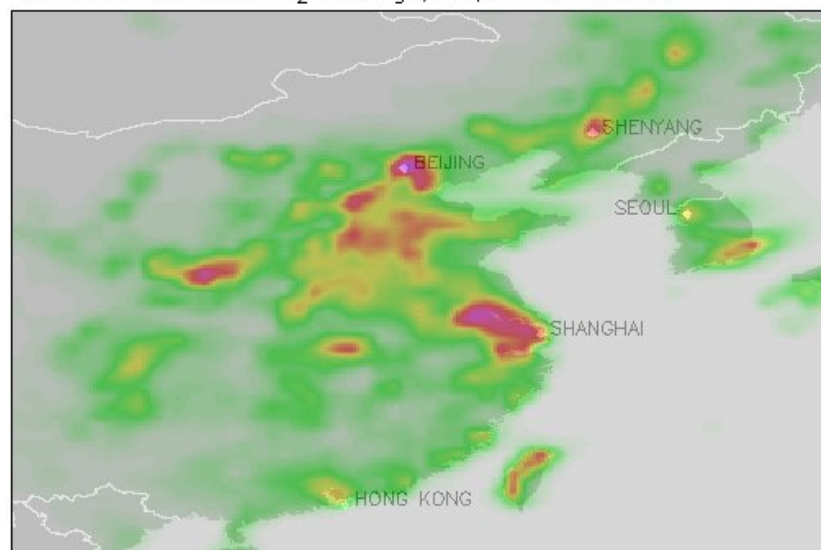
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Dust storm in
North East China
中国东北的沙尘暴



East China – NO₂ daily average

CHIMERE surface NO₂ average, F0, 06 Jun 2008



NO₂ concentration [$\mu\text{g}/\text{m}^3$] 0 20 40 60 80 100

Surface NO₂
concentration,
June 2006

Beijing's air quality

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Same place, different days...

Good



Worse



Bad



Chinese Air Quality Standards

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Pollutant	averaging period	Standard/guideline, $\mu\text{g.m}^{-3}$ according to:					
		WHO	EU	USEPA	China: limits by zone type -		
					I	II	III
TSP	Daily	X			120	300	500
	Annual	X			80	200	300
PM ₁₀	Daily	X	50 ^(25 ex)	150	50	150	250
	Annual	X	30	50	40	100	150
PM _{2.5}	Daily	-	-	65			
	Annual	-	-	15			
SO ₂	10 minutes	500	-	-	-	-	-
	1 hour	-	350 ^(4 ex)	-	150	500	700
	3 hour	-	-	1300	-	-	-
	Daily	125	125 ^(3 ex)	365	50	150	250
	Annual	50	20	80	20	60	100

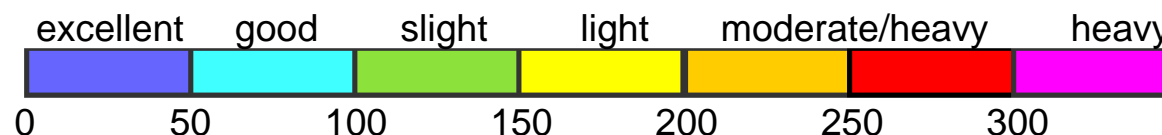
‘ex’ is number of exceedences allowed each year

Chinese Air Pollution Index (API)

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- defined by the China National Environmental Monitoring Centre
- API and species concentrations (mg/m³)

API	SO ₂ (daily mean)	NO ₂ (daily mean)	PM ₁₀ (daily mean)	CO (hourly mean)	O ₃ (hourly mean)
50	0.05	0.080	0.05	5	0.12
100	0.15	0.120	0.15	10	0.20
200	0.80	0.280	0.35	60	0.40
300	1.60	0.565	0.42	90	0.80
400	2.10	0.750	0.50	120	1.00
500	2.62	0.940	0.60	150	1.20

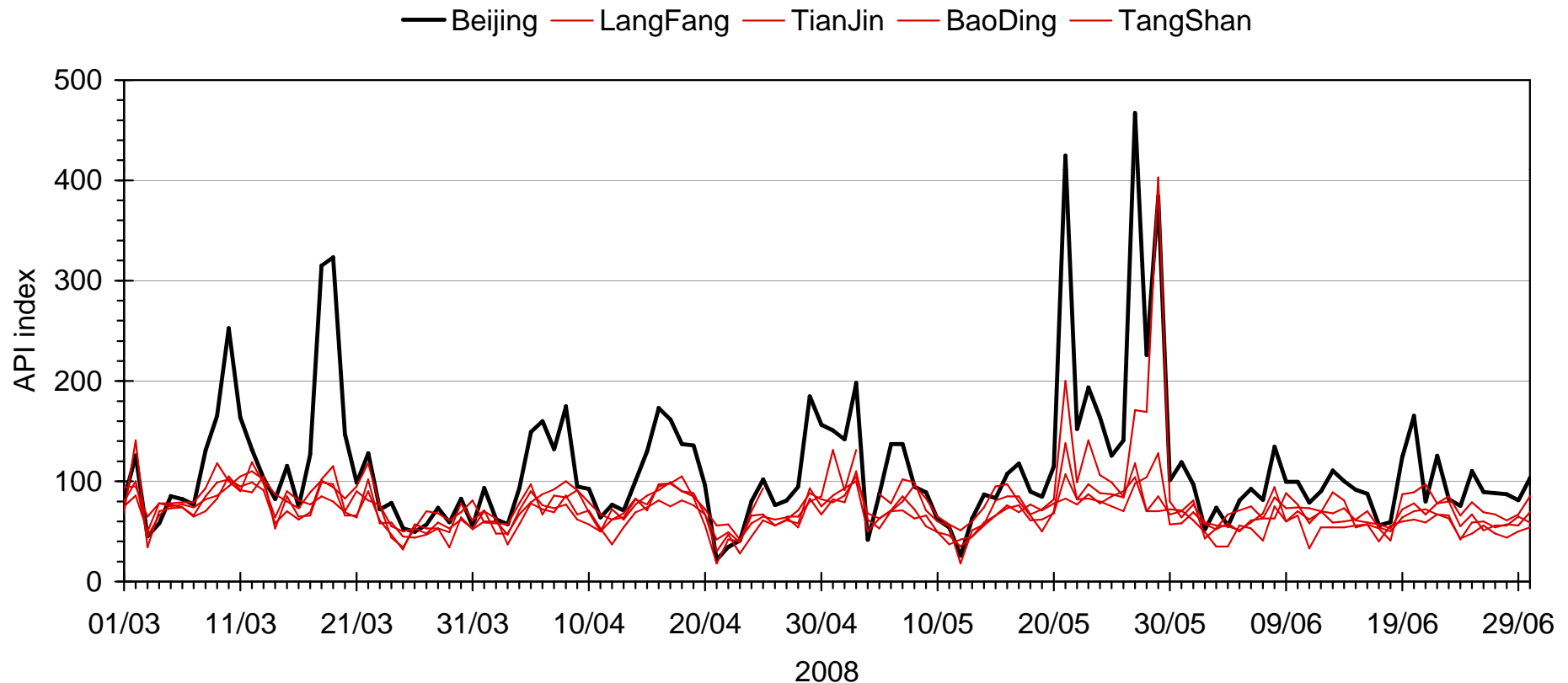


- May seriously affects people's health - mainly respiratory e.g. 10% Beijing population have some respiratory problems. Cost to economy of lost work days and of health care
- Impacts on natural environment - affects plant growth, crop yield, water quality etc.
- Visibility impairment

Beijing's air quality: API (March to June 2008)

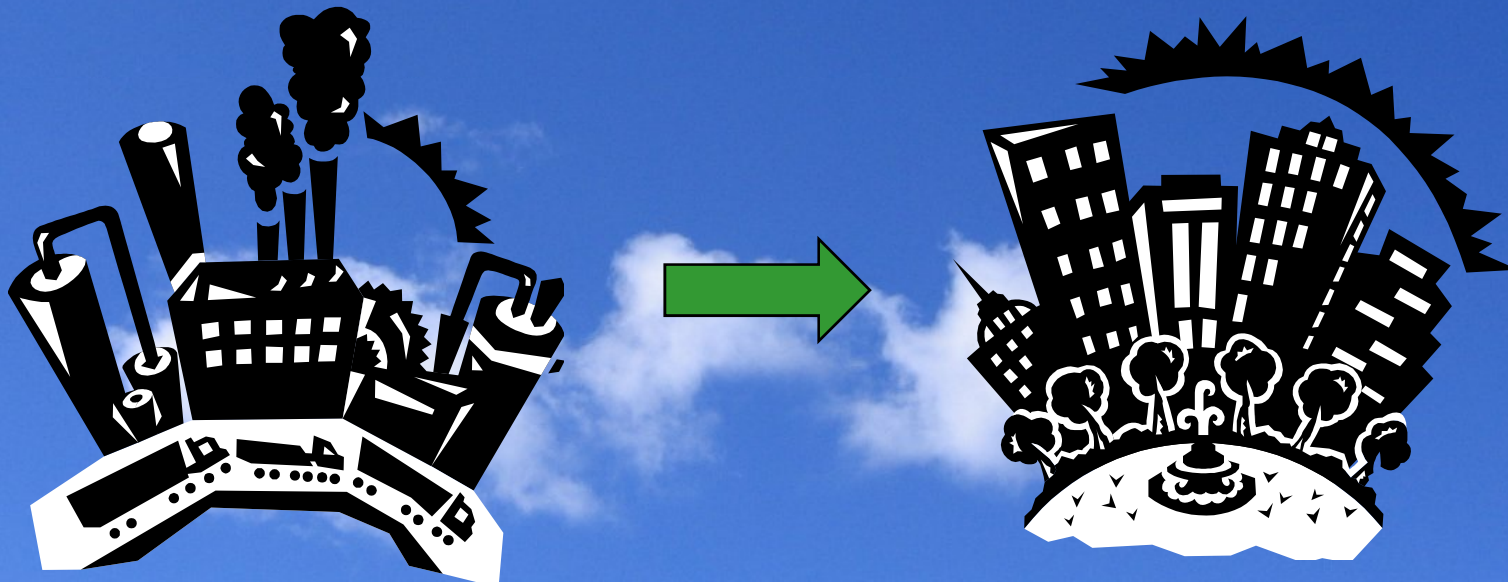
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API monitored by the EPBs of Beijing, Hebei and Tianjin



- Heavy reliance on coal; limited access to gas. Emissions of SO_2 result in local pollution and secondary particulates (due to oxidation of SO_2 , NO_x).
- Rapid economic growth – increasing demand for power.
- Rapid growth of traffic.
- Pollution is a mix of primary pollutants, secondary pollutants and wind born dust/particles including sand storms. Both local and regional sources.
- Monitoring
- Regulation

Mitigation strategies



Component parts of air quality management (I)

大气质量管理的组成 (I)

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Air Quality Objectives/ Standards 大气目标/标准	WHO or other standards 世界卫生组织或其它标准	
Emissions Inventory 污染排放清单	Industrial 工业	Process details, fuel usage, stack monitoring, stack characteristics 生产细节, 燃料用量, 烟囱监测,
	Transport 交通运输	traffic flows (counts or model), 交通流量(数数量或模拟) vehicle types, count, speed 车辆类型, 数量, 速度, Emission factors 排污系数
	Domestic/Services 民用/服务业	Fuel usage, emission factors, sulphur content etc 燃料用量, 排污系数, 含硫量等
Ambient Concentrations 气体浓度	Monitoring 监测	Collectors, continuous analysers (networked) 收集器, 连续监测仪 (网络化)
Models 模型	Air Quality 大气质量 Exposure/Health Impacts 暴露/健康影响 Economic 经济	

Component parts of air quality management II

大气质量管理的组成 (II)

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Abatement Measures 减污措施	Strategy 战略	Local, Regional, Industrial, Energy, Transport 地方，区域，工业 能源，交通 Policies, Modernisation, Use of New Technology 政策，现代化， 使用新技术
		Industrial 工业 Flue gas desulphurisation (fdg) 烟气低硫化 Clean coal 清洁煤 deNOx 低氮化 Particle traps 颗粒物收集器 Renewable energy 可再生能源
		Domestic 民用 Cleaner coal, Gas Conversions 更清洁煤，天然气 转化
		Traffic 交通 Catalytic Converters, Particle Traps 催化尾气净化 气，颗粒物收集器 Clean petrol 清洁汽油 Other technologies 其他技术
	Local Measures 地方措施	Siting of factories and stacks, stack heights 工厂和烟囱的选址， 烟囱高度 Efflux velocities, buoyancy, buildings, complex terrain effects 排放速度，浮力，建筑物，复杂地形影响 Siting of roads 道路选址 Low emission zones 低污染排放区 Traffic management 交通管理 Public Transport

Example I

Liaoning Integrated Environment Programme ^{CERC}

Improving Air quality in Fushun

辽宁综合环境项目的例子：抚顺空气质量

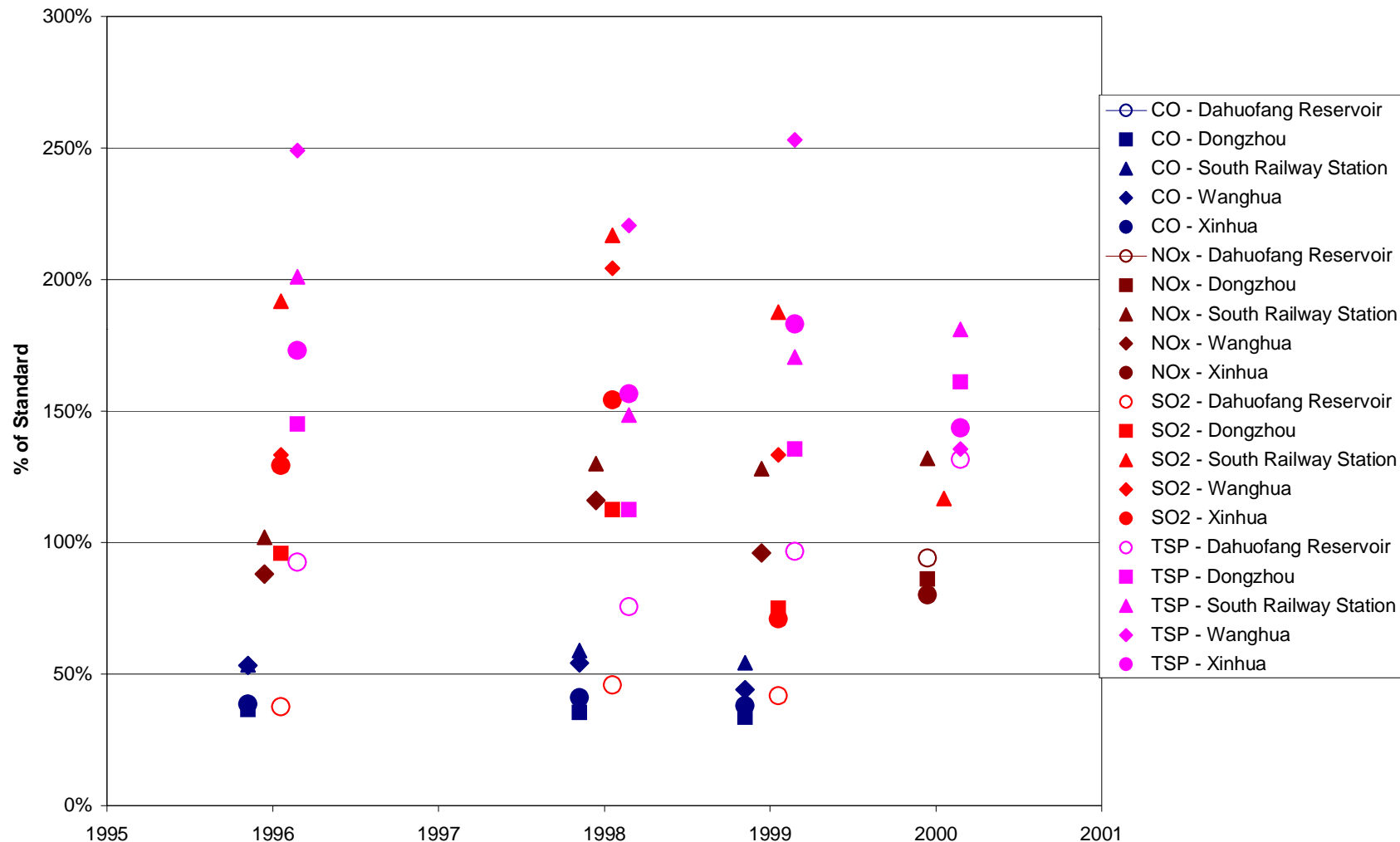


Liaoning Integrated Environmental Programme
欧盟 - 中国辽宁综合环境项目

Air quality in Fushun in 2000 抚顺的空气质量2000

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Comparison with Class 2 standard shows SO₂ and TSP of greatest concern



Aims of Investigation

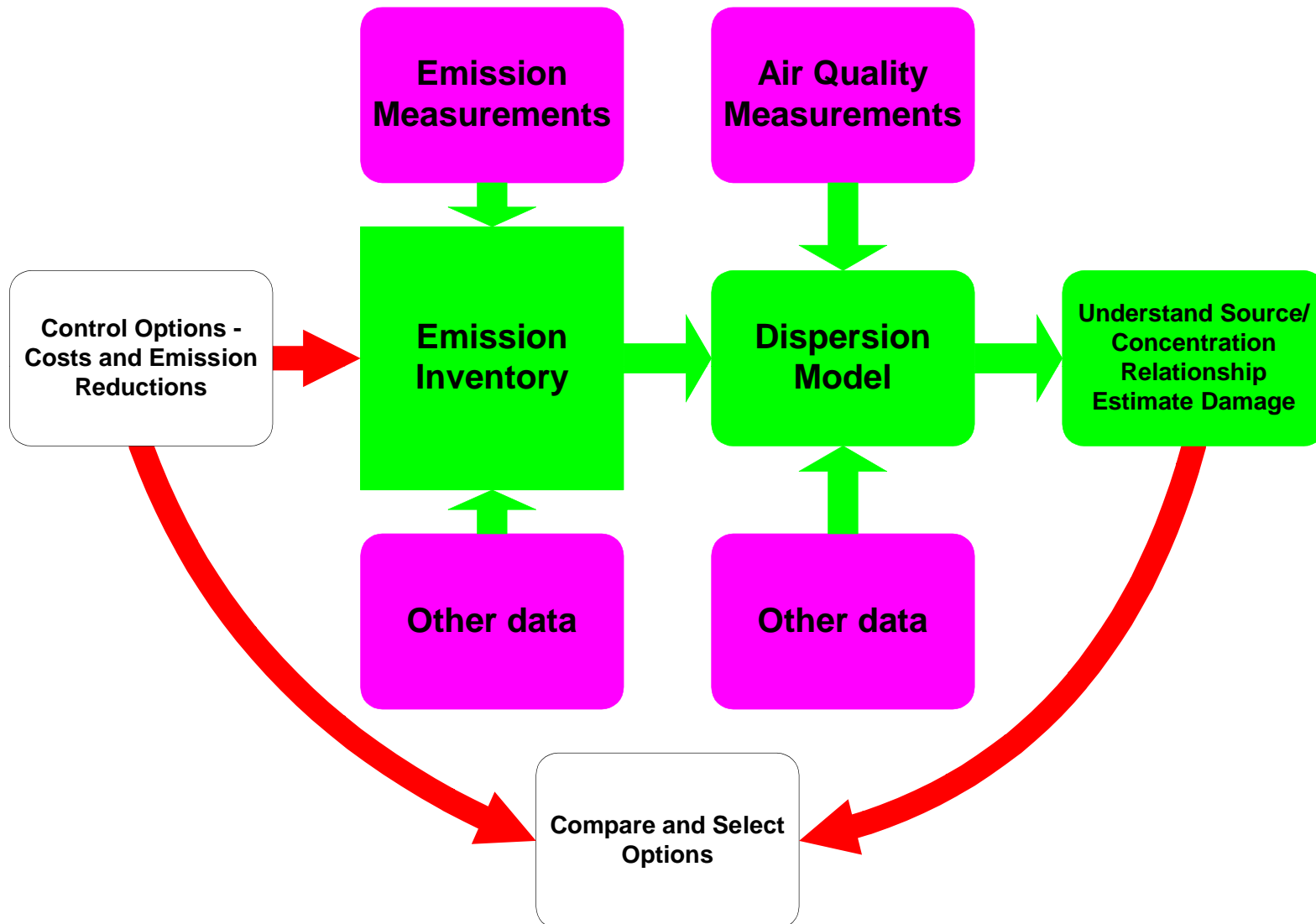
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- Assess how widely the Class II air quality standards will be exceeded or achieved
- Assess costs and benefits
 - Costs calculated from lost work days and health costs
 - Estimate over 2000 lost life-years in the year 2000 due to poor air quality
 - Those treated for pollution-related respiratory diseases in year 2000 account for 4% of the population
 - Cost in 2000 approximately 1.4% of Fushun's GDP
 - Projected population growth increases costs if no action is taken

- **Base Case本底情况**
 - Population growth & urban redevelopment人口增长，城市发展
 - District heating replacing local heating
 - Modernisation of single storey dwelling, reduce coal used
 - Industrial restructuring
 - Landscaping, reduce area of exposed soil by planting
- **Pollution Abatement污染削减**
 - Base case plus range of pollution abatement measures本底+一系列污染控制措施
 - Small boilers: fuel switching from coal to gas, diesel, coke
 - Large stacks: washed coal, layered combustion, desulphurisation, boiler closure, particulate abatement
- **Energy Efficiency能源效率**
 - Pollution Abatement plus energy efficiency programme污染控制+提高能源效率项目

Investigation process

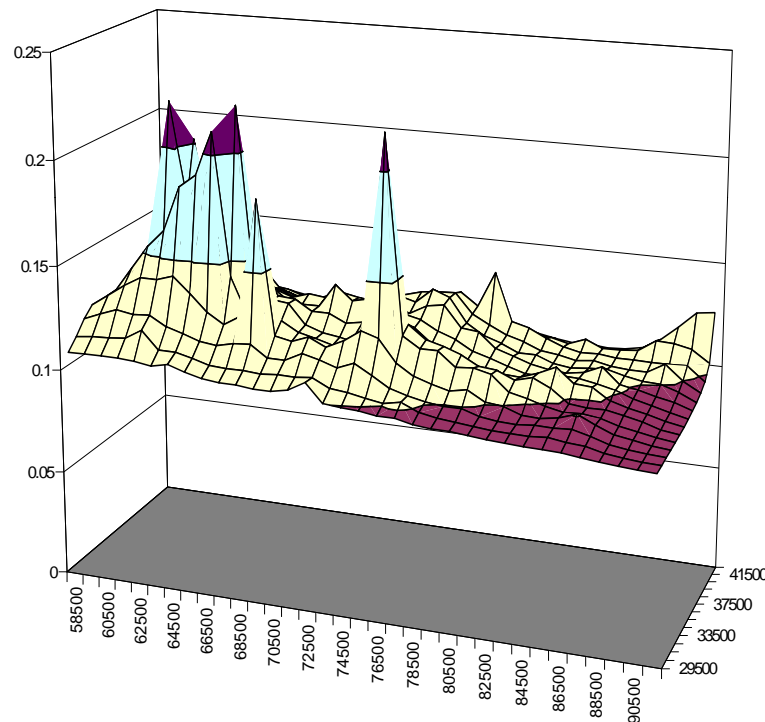
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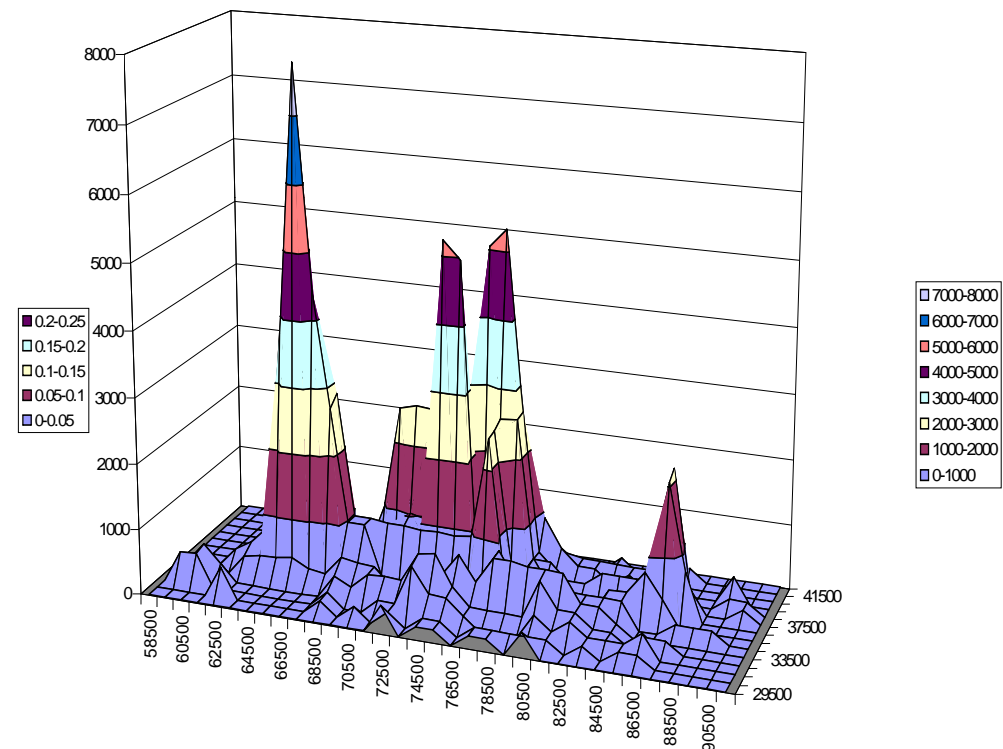
Modelling the strategies

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- Looked at the concentration (left) and also an exposure (right), to account for distribution of population
- $\text{exposure} = [\text{concentration} \times \text{population}]$ for each 1km^2



Concentrations
(mg/m^3)



Exposure
(person.mg/m^3)

Sources of TSP

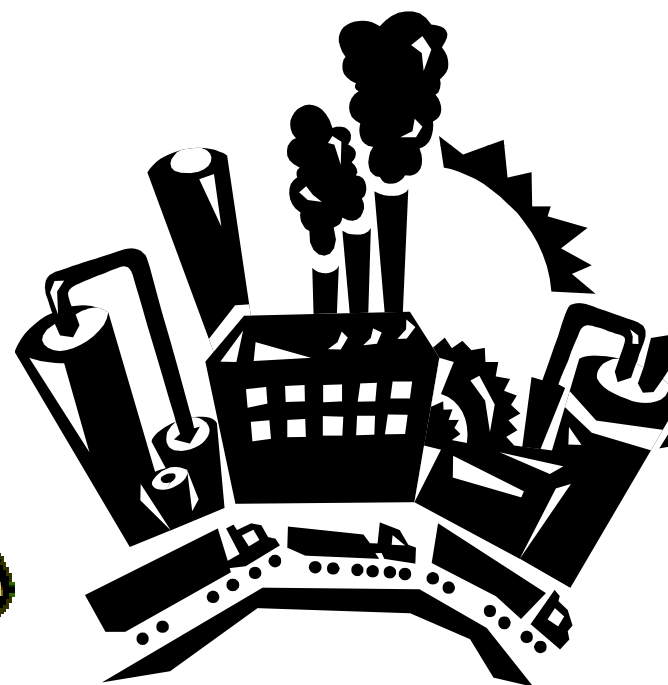
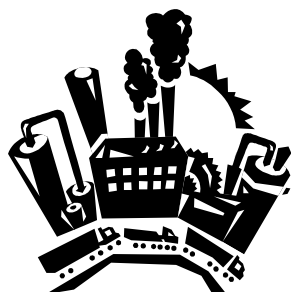
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- Analysis of the measured particulates and the modelling both show significant contributions to the annual average from remote sources and local fugitives, so potential for improvement is limited

The local emissions inventory approximately **29%**

Distant sources approximately **39%**

Local fugitives approximately **32%**



Sources of local emissions

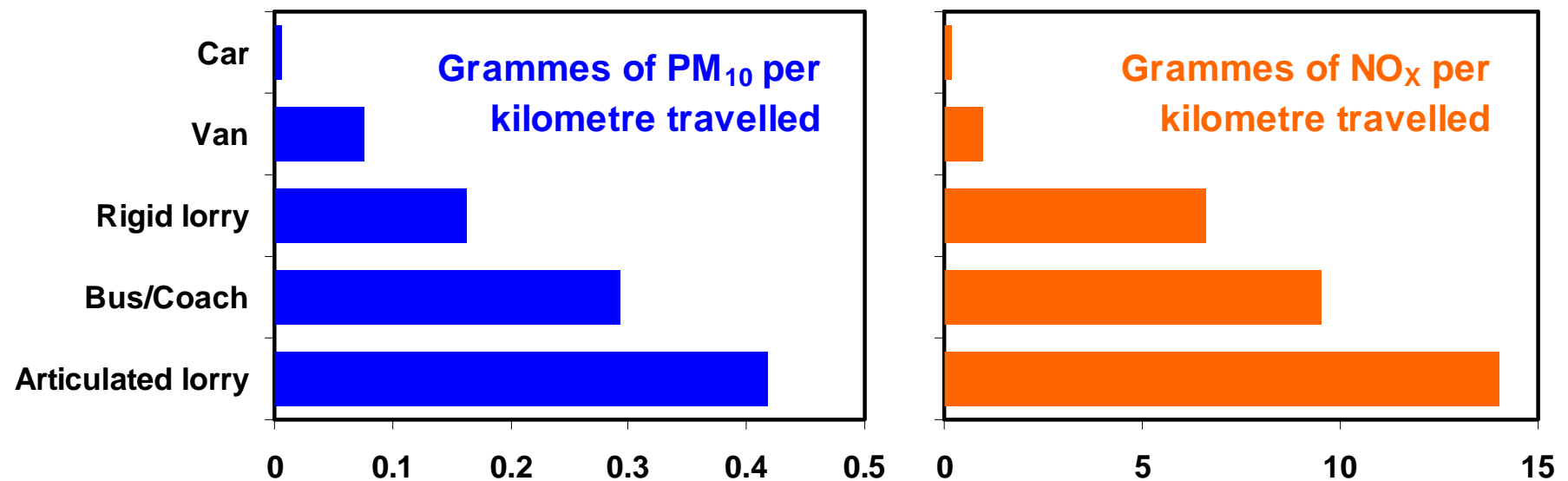
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- The heat and power sources and kilns are the biggest emitters amongst the inventory sources, year 2000 (tonnes)

		TSP	SO ₂	NO _x	CO
Point Sources	Cooking	82	58	43	8
	Heat & Cooking	133	171	133	27
	Heat	7195	7012	4391	1178
	Heat & Power	20729	27170	33788	758
	Power	45560	70116	75163	2140
	Production & Heat	2779	4599	3708	685
	Production	1199	1899	1830	185
	Kiln	27030	7495	4871	28
	Process	4325	2303	793	1775
Area Source	Small Industry	5898	354	78	1
	Small Boilers	968	729	109	1538
	Single Story Dwellings	2796	2953	419	6348
Road Traffic		1833	526	4946	141925
Transport -able Fugitive Dust	Road Dust	81608			
	Construction Dust	473			
	Storage Piles	52			
	Surface Dust	51998			
Total		254660	125386	130273	156595

Which vehicles? 那些车辆

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Lorries, buses and coaches have the highest emissions per kilometre travelled 大型运输车, 公共汽车等每公里的排污量最高

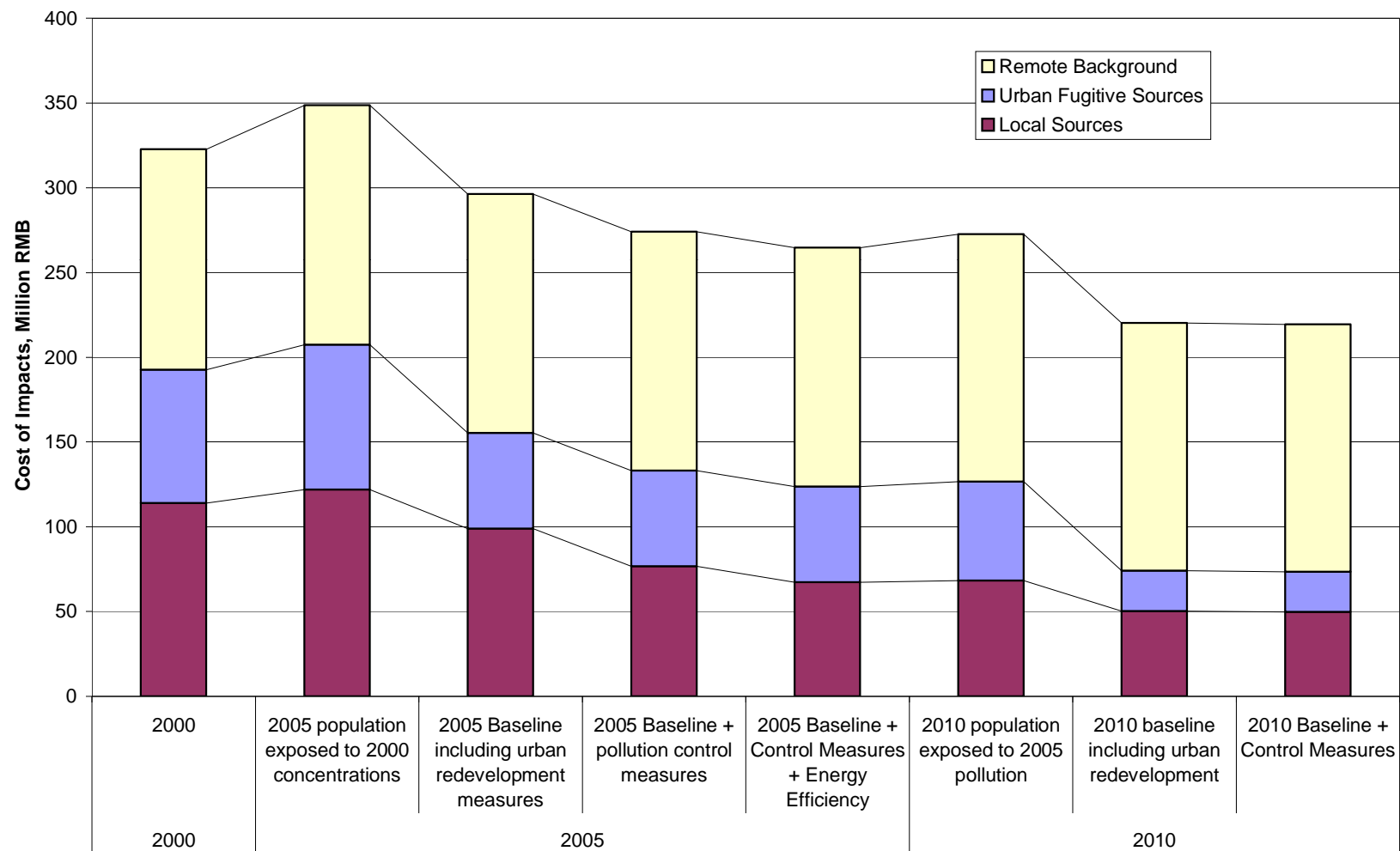


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Cost of impacts

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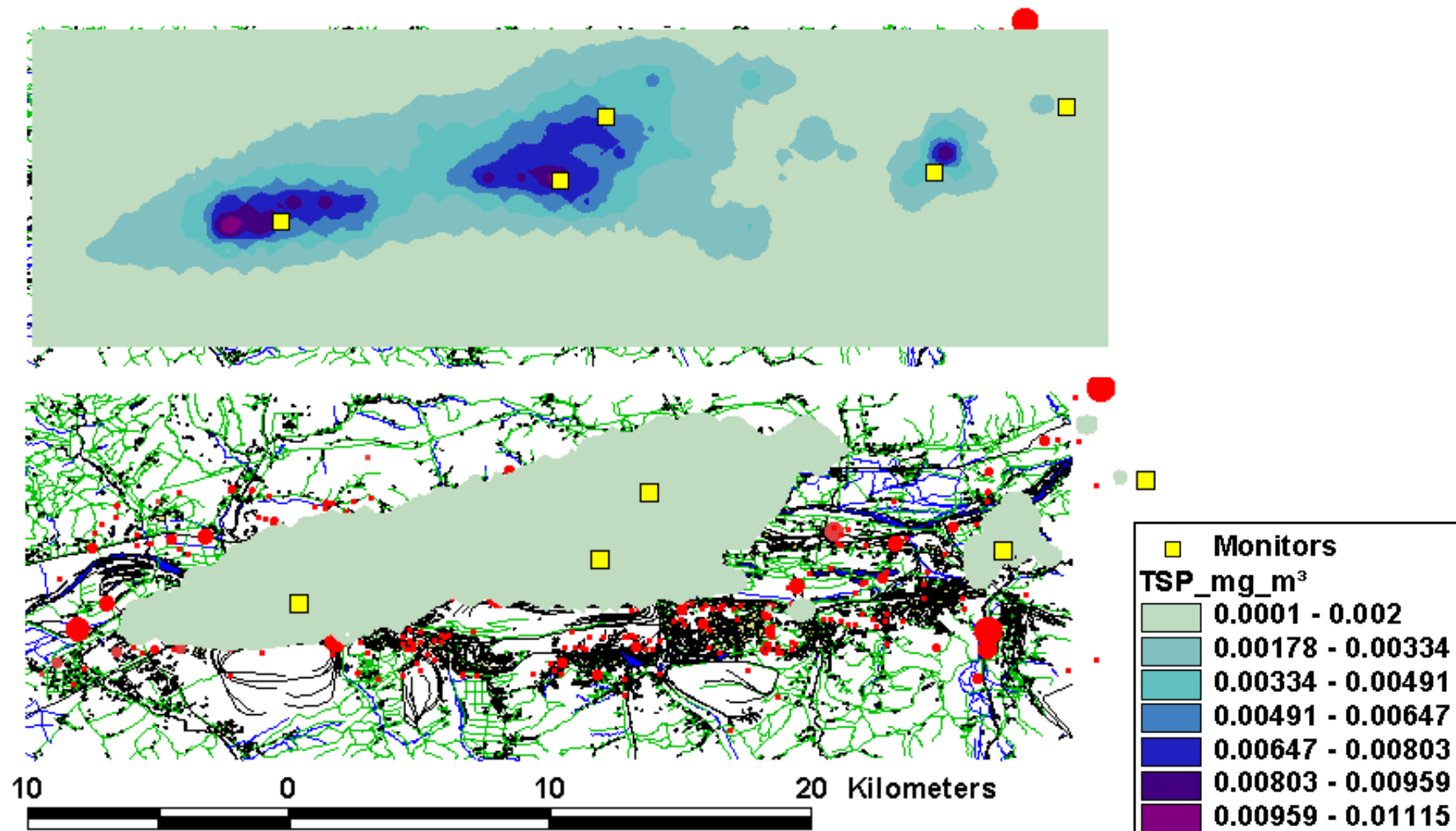
- No measures address the regional background - increasingly important



Fuel switching, small boilers, '00-'05

小型锅炉燃料转换 - 2000 - 2005

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- Urban restructuring significantly reduces the damage to health caused by air quality
- Local fugitive sources reduce dramatically due to the landscaping programme
- Proposed air pollution projects also cause significant improvements in air quality
- The cost benefit analysis can guide the investment choices – showed most of the benefit obtained by implementing 12 out of the 28 schemes
- There are significant cost savings from reduced coal use
- Energy efficiency measures in the industrial and domestic sectors can give significant health benefits at little or no cost, sometimes improving profitability
- If all the measures are implemented Class II standards will be met for SO₂ throughout Fushun but not for TSP

- The top 12 air pollution control, strategies comprise:
 - Large boiler closure programme
 - Energy efficiency programme
 - Large boiler particulate abatement programme
 - Small boiler control programme – fuel switching
 - Large boiler combined particulate /desulphurisation programme
 - Seven industrial dust control and facility upgrade projects
- Changes to the coal used by the large power plant to reduce sulphur content is not a cost-effective option
- Some plant upgrades would be costly and give little improvement in air quality

Example 2

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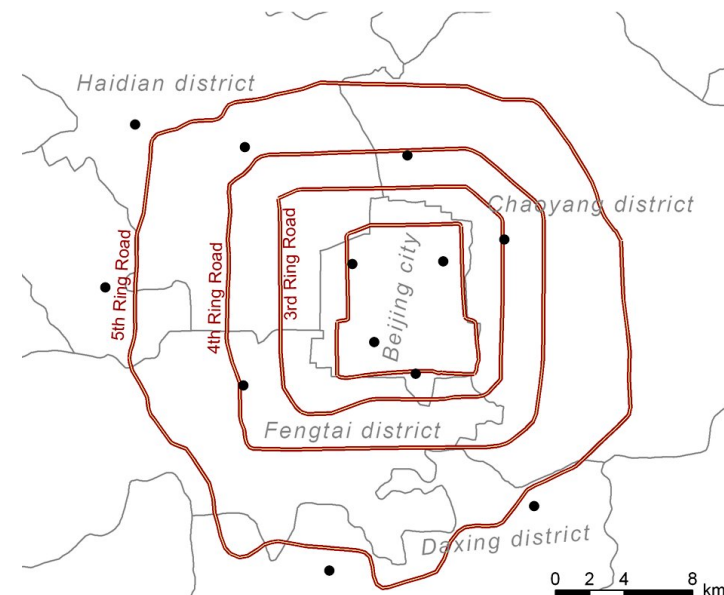
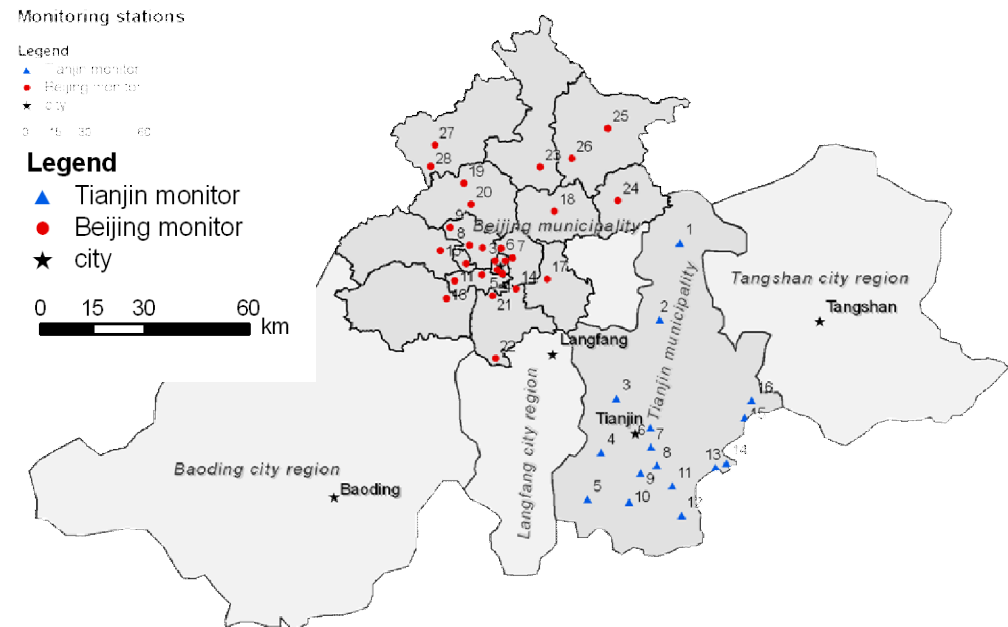
Improving and Forecasting Air Quality in Beijing



Monitoring the air quality in Beijing

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- Monitoring by Beijing Environment Protection Bureau (EPB)
- Pollution expressed as Air Pollution Index
 - daily value per monitor
 - daily average for Beijing
- Network of 27 monitors in the municipality of Beijing
 - 11 located in “central” Beijing



Monitoring the air quality in Beijing

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- Daily values published on-line daily at <http://www.bjepb.gov.cn>



The screenshot shows a Mozilla Firefox browser window displaying the website of the Beijing Municipal Environmental Protection Bureau. The page features a banner with the bureau's name in Chinese and English, and a logo. Below the banner, there is a section titled '空气质量日报' (Daily Air Quality Report) for the period from 2008年10月13日 12时 to 2008年10月14日 12时. The report contains a table with five columns: 监测子站 (Monitoring Substation), 空气污染指数 (Air Pollution Index), 首要污染物 (Primary Pollutant), 级别 (Level), and 空气质量状况 (Air Quality Status).

监测子站	空气污染指数	首要污染物	级别	空气质量状况
国控站平均	115	可吸入颗粒物	III级	轻微
东城区东四	132	可吸入颗粒物	III级	轻微
西城区官园	110	可吸入颗粒物	III级	轻微
崇文区天坛	106	可吸入颗粒物	III级	轻微
宣武区万寿西宫	107	可吸入颗粒物	III级	轻微
朝阳区奥体中心	110	可吸入颗粒物	III级	轻微
朝阳区农展馆	134	可吸入颗粒物	III级	轻微
海淀区植物园	104	可吸入颗粒物	III级	轻微
海淀北部新区	114	可吸入颗粒物	III级	轻微
海淀区万柳	114	可吸入颗粒物	III级	轻微
丰台区云岗	123	可吸入颗粒物	III级	轻微

- 10 years of planning and implementation of emission controls by the Beijing EPB to control air pollution
 - 13 programmes since 1998, 60 billion RMB
 - Four main categories of controls
 - reconstruction of energy supply
 - control of traffic
 - control of construction
 - control of industrial pollution
- Monitored concentrations of all major pollutants roughly constant or decreasing despite a growth in traffic of 10 % each year

Beijing's air quality: emission controls

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- Final stage on 20 July 2008
 - reduction in the use of private cars
 - further reduction in the use of government cars
 - a temporary halt to construction during the Olympic period
 - more cleaning of the roads to reduce dust
 - the suspension of heavily polluting industry
 - a reduction in production for coal-based enterprises



Vehicles restricted to operating on alternate days according to whether the final number on their licence plate is odd or even

Green sticker for Euro I (III) or above for petrol (diesel) vehicles



Signs alert drivers to areas of congestion and inform if the roads are free flowing



Higher polluting vehicles banned on urban roads from 1 July to 20 September - no yellow stickers



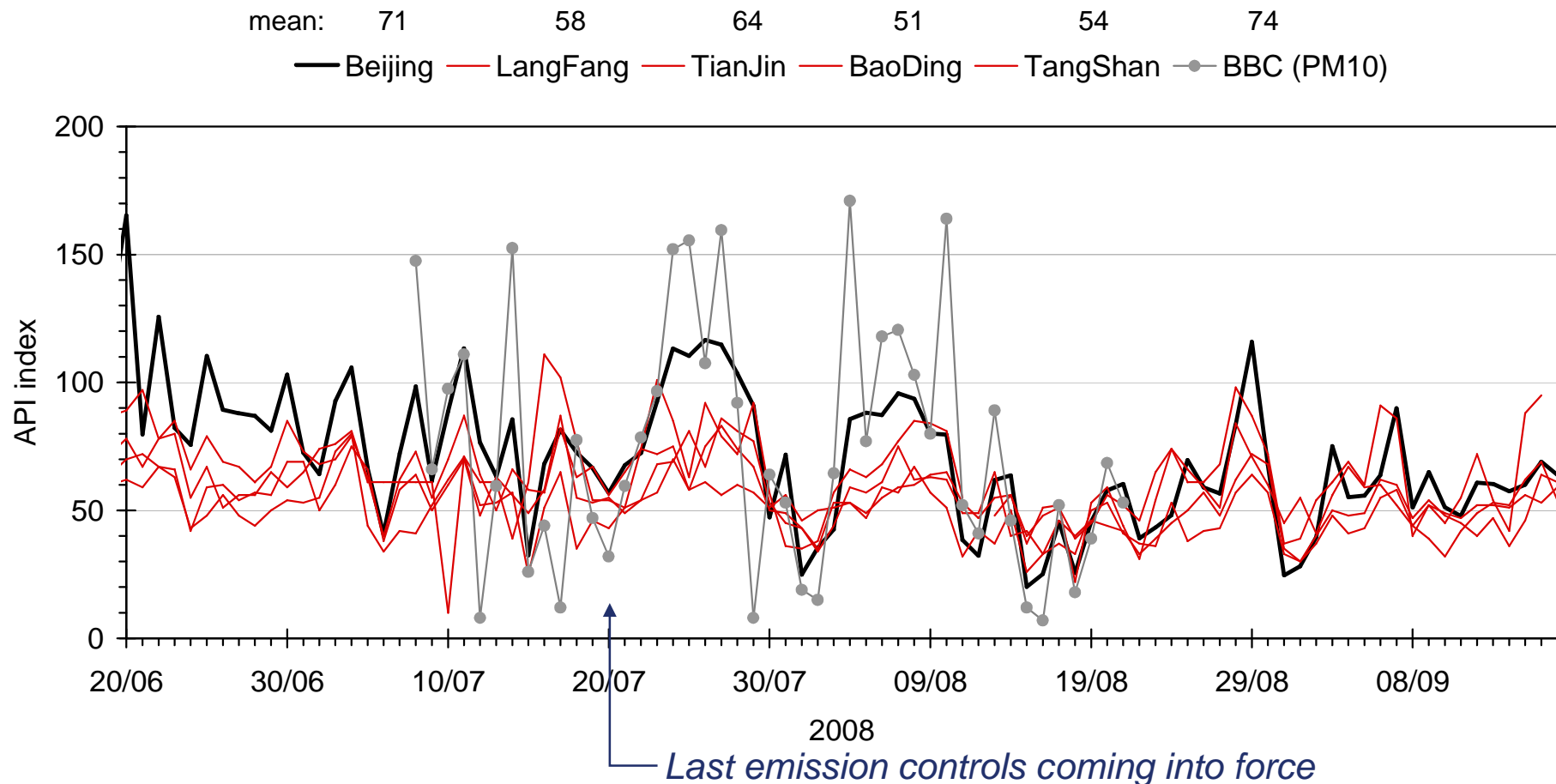
Special dedicated lanes should ease congestion for vehicles associated with the Olympics entitled to use them



Beijing's air quality: API (June to September 2008)

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API monitored by the EPBs of Beijing, Hebei and Tianjin
PM₁₀ measurements by a BBC reporter James Reynolds



Results

- Colour contours of total API, TSP, NO₂, SO₂ and O₃
- Detailed contours around Olympic stadium, Olympic village and tourist sites in the centre of Beijing
- Less detailed contours elsewhere in the city

Dissemination

- Results posted with a text summary to a website
- Website in Chinese and English
- Forecast sent 1x or 2x/day
- Forecast e-mail bulletins 2x/day



BeijingAir 北京

BeijingAir: website

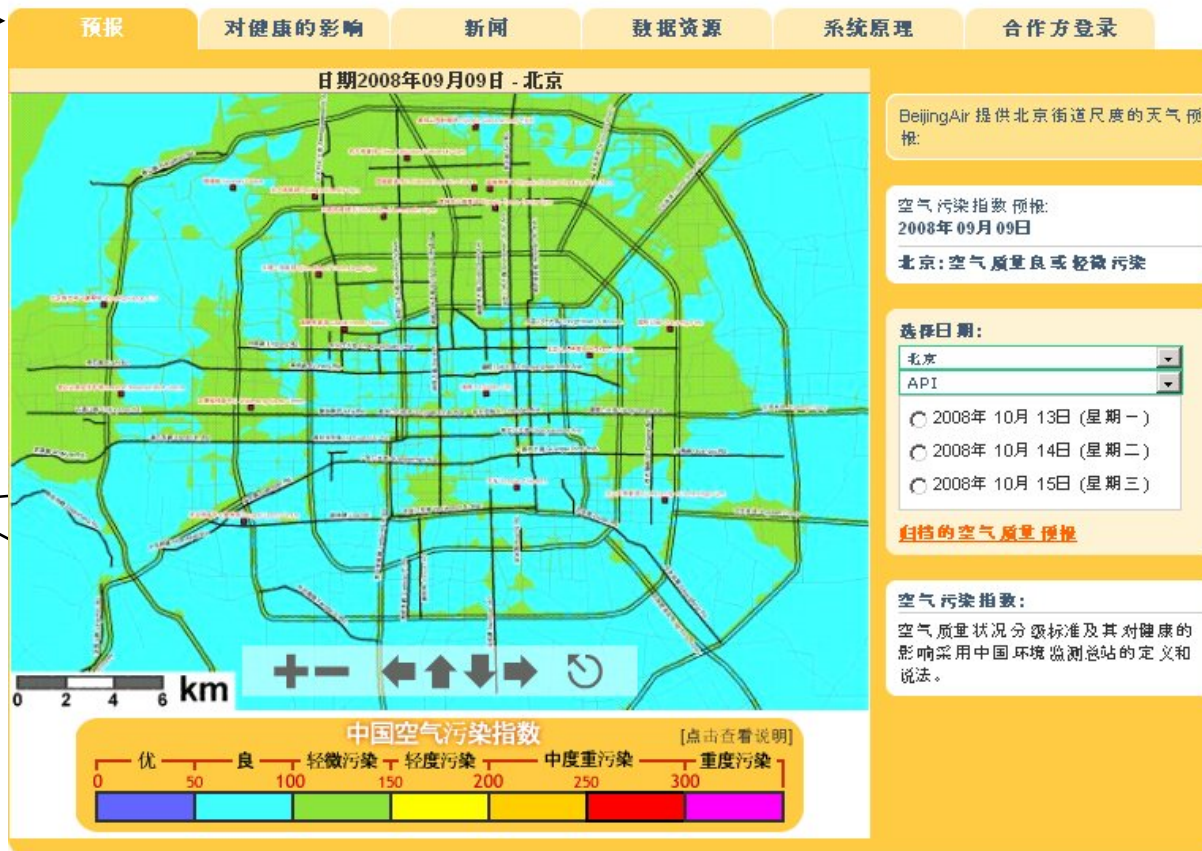
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BeijingAir 北京 — DRAGON 龙计划
北京空气质量预报

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字体: 正常 | 较大 | 特大 | 文本格式

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Main tabs →



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Interactive map

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BeijingAir: website (health)

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BeijingAir 北京 • DRAGON 龙计划

Partner log In
English | 中文
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Air quality forecasts for Beijing

forecasts

health effects

news

data resources

how it works

partner login

Health effects of air quality

Definition of Air Pollution Index (API) in terms of concentrations (PDF file)

Depending on how high pollution levels are forecast to be, there are various simple steps you can take to reduce the likelihood of any impacts on you. The action you can take depends on the level of pollution expected. Pollution levels in the People's Republic of China are expressed using the Air Pollution Index (API) defined by the government. The overall Air Pollution Index includes particulates, nitrogen dioxide and sulphur dioxide.

SLIGHTLY
POLLUTED

LIGHT
POLLUTION

MODERATE
POLLUTION

MODERATE
TO HEAVY
POLLUTION

HEAVILY POLLUTED

API 100-150

API 151-200

API 201-250

API 251-300

API 301+

What health effects may I
notice?

- Those who are susceptible may experience slight deterioration in symptoms.
- The general public may experience some irritation.

What can I do?

- People with heart disorders or pulmonary disorders should avoid physical exertion and outdoor activities.

What health effects may I
notice?

- Those who are susceptible will experience severe deterioration in symptoms. Their tolerance for exercise decreases.
- The wider general public will experience some symptoms.

What can I do?

- The elderly and people with heart disorders or pulmonary disorders should remain indoors and reduce their physical activities.

What health effects may I
notice?

- The general public will experience decreased tolerance for exercise with obvious and severe symptoms.
- Some diseases may be prematurely induced.

What can I do?

- The elderly and people with heart disorders or pulmonary disorders should remain indoors and avoid physical activities.
- The general public should avoid outdoor activities.

BeijingAir provides street-scale air
quality forecasts for Beijing:

Forecast of Air Pollution Index for:
Tuesday 9 September, 2008

**Olympic Green: Generally slightly
polluted.**

Air Pollution Index:

The definitions of air pollution levels and health effects used are those defined by the China National Environmental Monitoring Center.

- Air Pollution is a major challenge to China.
- Heavy Reliance on Coal.
- Impacts on health, natural environment and visibility.
- Pollution is a mix of local emissions industry, traffic, domestic heating, dust) and regional pollution caused by generation of ozone and oxidation of acid gases (SO_2 and NO_x) and hence production of secondary particulates (haze).
- Solutions can draw from success of integrated approach used in Europe (CAFÉ). Requires both local **and** regional control measures. No easy solutions.
- When levels are particularly high, temporary local measures (eg switching off factories) can be effective for short term benefit.
- Long and short term planning require modelling - to test options - and air quality forecasting for short term alerts/ measures.

Thank you

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