

City clusters in China: air and surface water pollution

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City clusters are made up of groups of large, nearly contiguous cities with many adjoining satellite cities and towns. Over the past two decades, such clusters have played a leading role in the economic growth of China, owing to their collective economic capacity and interdependency. However, the economic boom has led to a general decline in environmental quality. This paper will review the development and current status of the major environmental problems caused by city clusters, focusing on water and air pollution, and suggest possible strategies for solving these problems. Currently, deteriorating water quality is of major concern to the public and decision makers alike, and more than three-quarters of the urban population are exposed to air quality that does not meet the national ambient air quality standards of China. Furthermore, this pollution is characterized by high concentrations of both primary and secondary pollutants. Environmental pollution issues are therefore much more complex in China than in western countries. China is expected to quadruple its GDP by 2020 (using 2000 as the base year for comparison) and, consequently, will face even more serious environmental challenges. Improving energy efficiency and moderating the consumption of natural resources are essential if China is to achieve a balance between economic development and environmental health.

摘要: 中国的城市群由空间距离很近的大城市及周边的若干卫星城镇组成。过去 20 余年里, 由于城市群内的经济规模优势和城市间的相互支撑, 城市群在中国的经济发展中起到了引领的作用。然而, 经济的繁荣也带来了环境质量的退化。本文以大气和地表水污染为重点, 回顾城市群引起的环境质量的演变过程及目前的状况, 并对解决这些问题提出可能的战略建议。当前, 水质恶化是公众和决策者关注的一个重大问题, 而超过 3/4 的城市人口呼吸着超过国家空气质量标准的空气。更重要的是, 中国的环境污染具有一次污染物和二次污染物同时具有高浓度水平的特征, 污染问题因而要比西方国家复杂。到 2020 年, 中国的 GDP 将在 2000 年的基础上增长 4 倍, 因此将面临更为严峻的环境压力。中国在未来发展中要寻求经济增长和环境健康之间的平衡, 推进提高能源效率和自然资源的适度消耗将是关键的因素。

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China has experienced unprecedented economic growth over the past two decades, accompanied by the development of large-scale industries and services. In the course of this expansion, medium-sized cities and

small towns have sprung up around the larger cities, forming city clusters, often with similar or interdependent economies.

The development of city clusters in China is somewhat similar to the formation of the megalopolis in the United States, as described by Gottmann (1961). However, there are some differences in terms of the number of cities in an area, their infrastructure, and the services they provide to the region, as compared to the US. City clusters in China tend to be much more concentrated and densely populated, with little room for natural areas; for example, the distance between cities is often less than 10 km in the Pearl River delta. In the city of Guangzhou, spacing between residential buildings is so restricted that they are often referred to as “handshaking” buildings. Also, there is no clear, functional division of infrastructures among the cities, due to a lack of coordination between city planners. Cities within a cluster often compete for avail-

In a nutshell:

- The emergence of city clusters, large groups of cities and towns in close proximity to one another, has contributed to China's rapid economic growth over the past 20 years
- However, environmental quality has deteriorated within and around these clusters, with pollution issues becoming widespread
- Air pollution, especially increasing levels of fine particles and ground-level ozone, is a growing environmental problem in city clusters, and a multi-objective strategy is necessary for effective control
- China must improve its energy efficiency and resource consumption in order to achieve environmentally friendly economic development and a sustainable society

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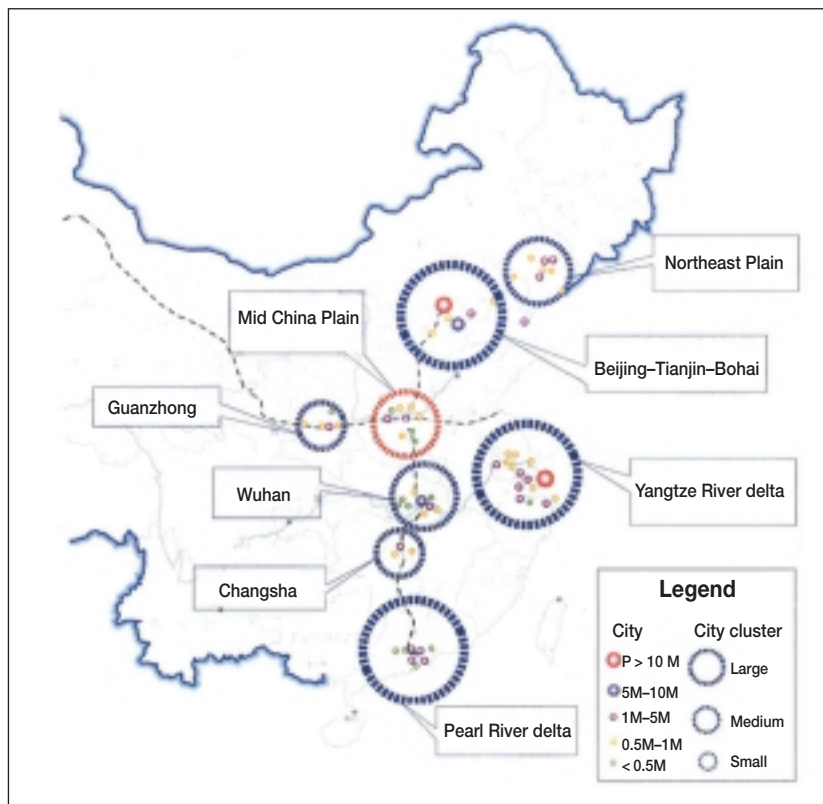


Figure 1. The distribution of city clusters in eastern China. The closed dots indicate cities, sized according to urban population size; the dashed circles indicate city clusters, sized according to GDP. Details of the Northeast plains, Beijing–Tianjin–Bohai Bay area, Yangtze River delta, and Pearl River delta are given in Table 1; the other city clusters are generally development zones around one large city. Central-China plains, Guanzhong, Wuhan, and Changsha are used as names of city clusters near the cities of Zhengzhou, Xi’an, Wuhan, and Changsha cities, respectively. Redrawn from Zhang (2004).

able natural resources, investment, and regional funding for infrastructure development and improvement. For example, five separate international airports have been constructed in recent years in the Pearl River delta (including Hong Kong and Macau). Better intercity cooperation could avoid such wasteful redundancy in the future, resulting in a more efficient regional economy (Bao 2005).

If, as expected, such rapid development continues over the next several decades, demographic trends suggest that China will experience an even greater rate of urbanization. Population in urban areas has already increased from 20.0% of the total population in 1980 to 36.1% in 2000 (National Bureau of Statistics 2001a), and reached 37.8% in 2003 (Li and Ji 2003). Despite this rapid pace of urbanization, current levels are still far below the global average (48.3% in 2003; United Nations Population Division 2004). There is still great potential for further urbanization, therefore, particularly as the urbanization process catches up with the pace of industrialization, which is often just as fast in villages (National Bureau of Statistics 1999).

The combination of rapid economic growth and urban-

ization has resulted in substantial environmental problems throughout China, but nowhere more so than in city clusters. A considerable part of China’s GDP was achieved at the cost of over-consumption of energy and other natural resources. The Pearl River delta, for example, although accounting for only about 20% of Guangdong province, consumed 67% of the coal and 85% of the oil for the entire region. Due to the close proximity of the cities and the large number of emissions sources, ambient concentrations of SO₂ and NO₂ in the Pearl River delta region were 2–3 times the level found in other parts of the province (CESPKU and GIES 2004). Pollutants from various cities in the area tend to mix and spread over the entire region (Wang SL *et al.* 2005).

There is an urgent need to incorporate environmental issues into planning China’s urban areas, in order to reduce the risks of further environmental degradation. This paper briefly describes the role of city clusters in China’s economic development, and describes the regional air and watershed pollution that has developed as a result of the rapid economic growth within these city clusters. We also propose possible solutions to these environmental problems, taking into account the social and economic plans for medium- and long-term development in China.

■ Economic growth in city clusters

Urbanization in China has occurred most rapidly in the coastal areas, due to the stronger economic base and more developed infrastructure, as well as the greater abundance of natural resources. As a result, several city clusters have arisen in coastal areas and nearby regions (Figure 1). For several reasons, the formation of city clusters often acts as a catalyst for economic growth and enhances the competitiveness of the region as a whole. The central government has therefore developed long-term plans to support rapid coastal urbanization, followed by efforts to increase urbanization, in the central part of the country, thereby aiding economic development (National Bureau of Statistics 2001b). In essence, the three largest city clusters – the Beijing–Tianjin–Bohai Bay, Yangtze River delta, and Pearl River delta regions – have become the forerunners of modernization in China.

At present, the Yangtze River delta and Pearl River delta areas are the most fully developed, followed by the Beijing–Tianjin–Bohai Bay cluster and the recently initiated Northeast cluster (Table 1). The Pearl River delta city cluster has expanded rapidly since the 1980s, due primarily

to former political leader Deng Xiaoping's policy of creating "special economic zones", designated regions where governmental policy fosters a market economy instead of a planned economy. Similarly, the exponential economic growth of Shanghai in the 1990s led rapidly to accelerated growth among cities in its neighborhood. The Beijing–Tianjin–Bohai Bay area is a unique city cluster that formed spontaneously around the twin megacities of Beijing and Tianjin.

The Northeast plains cluster, the former national center for heavy industry from the 1950s and throughout the 1980s, is now facing major challenges in maintaining its economic strength, following the exhaustion of its once abundant natural resources, especially coal, oil, and iron ore. Industrial restructuring and rehabilitation are making the Northeast cluster China's fourth economic pillar (Table 1). While these four regions make up less than 3% of China's territory, and encompass only about 12% of the country's total population, they account for nearly half of the national GDP (47% in 2001; National Bureau of Statistics 2002).

Although the government has also supported increased urbanization of small towns (Bai 2002), it is the large city clusters that are expected to drive economic development for the foreseeable future (Li and Ji 2003). Even so, it is widely predicted that millions of people will migrate from rural areas to adjacent urban areas over the next several decades, leading to the widespread growth of small and medium-sized cities, some of which are likely to become part of future city clusters. For instance, Henan Province, formerly a relatively poor agricultural province but with the largest population of any of China's provinces, has since grown to become the fifth largest provincial economy in China, based on GDP (2004 statistics; Zhang 2005). This economic expansion was due primarily to urban migrations and a subsequent shift in the economic base, from agricultural to industrial. Meanwhile, the Central-China plains city cluster in the same province is also growing very quickly. These developments are seen as a rejuvenation of economic strength in central China.

The city clusters have major advantages in terms of regional economic development: the drop in GDP due to environmental pollution resulting from such rapid economic growth has largely been ignored. In 1997, a World Bank report indicated that economic losses caused by environmental pollution in China ranged from 3–8% of GDP, which attracted the attention of both policy makers

Table 1. The contribution to national GDP from the four major city clusters in 2002

City clusters	Number of cities	Megacities	Area (1000 km ²)	Population (million)	GDP per capita (1000 yuan person ⁻¹)	Percentage in national GDP (%)
Pearl River delta	25	Guangzhou, Shenzhen	41.7	23.0	35.7	11.4
Yangtze River delta	43	Shanghai, Nanjing, Hangzhou	99.6	75.3	22.5	23.7
Beijing–Tianjin–Bohai Bay	9	Beijing, Tianjin, Tangshan	55.3	35.1	14.2	7.0
Northeast plain	17	Shenyang, Dalian	77.1	27.0	13.5	5.1

National Bureau of Statistics (2002)

and academics (World Bank 1997). Although later estimates provided different numbers, by the end of the 20th century, economic losses due to environmental pollution were probably around 4–5% of GDP, which is comparable to the 5% estimated for the US in the mid-1970s and the 3–5% estimated for the European Union in the mid-1980s (Xu 1998). However, there are no truly reliable estimates of the impact that pollution from city clusters has on GDP, despite the importance of the issue.

■ Watershed pollution

China has insufficient water resources. The amount of fresh water available per capita is about one-quarter of the global average of 8513 m³ per year (2002 statistics; World Bank 2003). In a survey of more than 600 Chinese cities, two-thirds had inadequate water supplies, while 1 in 6 experienced severe water shortages (Li 2003). Water pollution caused by rapid urbanization and the formation of city clusters has exacerbated the lack of accessible drinking water. While levels of industrial wastewater discharge have largely stabilized, domestic wastewater has increased considerably. While the total amount of released industrial wastewater fluctuated around 22 billion tons from 1995 to 2004, the domestic sewage discharge increased from 13.1 billion tons in 1995 to 22.1 billion tons in 2000, and up to 26.1 billion tons in 2004 (State Environmental Protection Administration [SEPA] 1995–2004). This was due primarily to the enactment of more stringent controls on industrial sources of wastewater; in 2003, 91% of industrial wastewater was treated, in contrast to only 32% of urban domestic sewage (National Bureau of Statistics 2004).

As a consequence, surface water quality has become an issue of great concern in China. A national survey of seven major rivers in China, carried out in 2004, revealed that water quality measurements in 28% of 412 monitored sections were below grade V, the worst grade in the national standard for water quality in China. These results indicate that, for these sections of river at least,

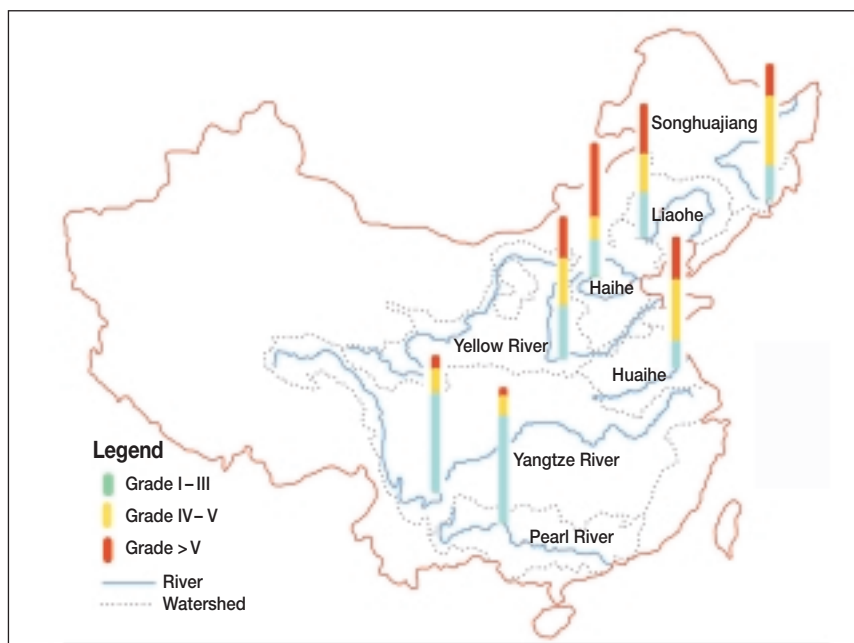


Figure 2. Water quality of seven major rivers in China. The length of the bars are normalized to 1; the lengths of the green, yellow, and red bars represent the percentages of each river section with water quality between grades I–III, between grades IV–V, and grade V or worse, respectively. (According to the national surface water quality standards of China [GB3838-2002], water of grades I–III is suitable for drinking, grade IV is for industrial and recreational use, and grade V is for agricultural use).

the water supply is virtually of no practical or functional use, even for agricultural irrigation. For the Haihe River, which provides the cities of Beijing and Tianjin with the bulk of their drinking water, this figure was as high as 57%, and for the Liaohe River, which supplies water to Northeast China, it was 38% (see Figure 2 for the locations of these rivers). Overall, more than 90% of the river sections that flowed through urban areas showed a water quality of grade V or worse (SEPA 1995–2004). The higher the grade, the worse the water quality; only water with a grade lower than III is drinkable. The same survey suggested that even the water quality of the Yangtze and Pearl Rivers, both of which have relatively abundant water flow, was a cause for concern; approximately 10%

of the monitored sections of these two rivers also revealed water quality worse than grade V, and all monitored sections in the urban area of Guangzhou (on the Pearl River) had water quality around grade V or worse. The water quality of the rivers shown in Figure 2 was characterized only by conventional indicators, such as chemical oxygen demand (COD), ammonia, and volatile phenols, among others. The situation is even more worrisome when endocrine disrupting organic substances are taken into consideration as well (An and Hu 2006).

Lake Taihu, the third largest freshwater lake in China, provides a typical example of water pollution caused by city clusters. With a total watershed area of about 36 500 km², Taihu is situated within Jiangsu and Zhejiang provinces. The city of Shanghai, as well as more than 37 other cities and towns, is sited within its watershed. GDP in the area around Lake Taihu increased by a factor of 17 between 1980 and 1998; per capita GDP in the area was three times the national average (State

Council of China 1998), while the population density was eight times the national average (Gao *et al* 2003). The water quality of Lake Taihu has deteriorated greatly during this period (Figure 3), largely as a result of this rapid economic growth. The lake remains the most important source of drinking water for the inhabitants of the Yangtze River delta region, but water quality has dropped by approximately one grade level every decade (Qin *et al.* 2004), and in 2004 nearly 60% of sampling sites in the lake recorded water quality lower than grade V (SEPA 1995–2004). As a result, the entire watershed area is now facing a shortage of potable water. Residents in the area who enjoyed the clean water of the lake in the past are now compelled to buy bottled water for drinking.

According to Gao *et al.* (2003), over 80% of COD and 70% of total phosphorus originated from urban and residential areas around the lake, with 42% of COD and 60% of total phosphorus derived from domestic sewage discharge. Research has shown that increased phosphorus concentration is the key factor in the worsening eutrophication of Lake Taihu (Dokulil *et al.* 2000); domestic sewage is therefore clearly a major source of water pollution in the lake. Future conversion of agricultural areas in the watershed to urban environments will very probably lead to even greater levels of water pol-

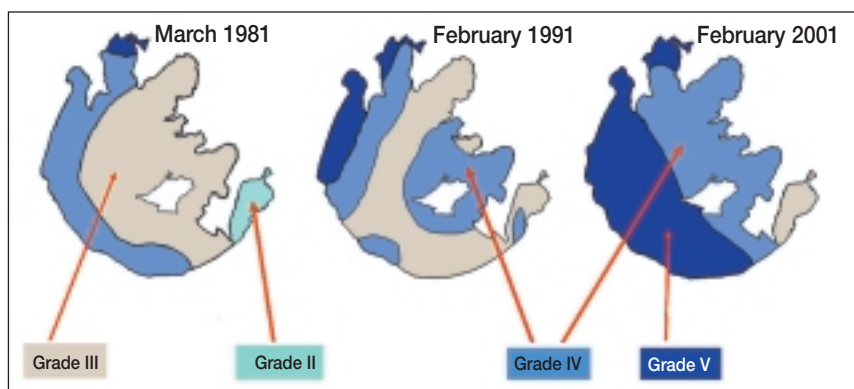


Figure 3. Historical trends in water quality in Taihu lake. The water quality grading system is the same as in Figure 2. (Derived from monitoring data provided by National Environmental Monitoring Center.)

lution (Gao *et al.* 2003). The deteriorating condition of Lake Taihu is typical of the problems associated with the increasingly polluted nature of China's sources of freshwater, and illustrates the urgent need to integrate both water pollution and population controls into the planning for future economic development in the country's watersheds.

■ Regional air pollution

Air pollution is perhaps China's biggest environmental problem. Results from routine monitoring of 360 cities in 2004 revealed that the air quality of nearly 70% of urban areas did not meet the country's national ambient air quality standards (NAAQS), and that nearly 75% of urban residents were regularly exposed to air considered unsuitable for inhabited areas (SEPA 1995–2004).

China has high levels of sulfur dioxide (SO₂) and total suspended particulates (TSP), because coal is the source of 60–70% of its primary energy. Meanwhile, the number of motor vehicles has increased substantially since the mid-1980s, primarily in urban areas and city clusters; in Beijing, for example, the number of vehicles increased from 0.5 million in 1990 to 2 million in 2002 (Beijing Municipal Bureau of Statistics 2003). The growing number of cars and trucks has led to much higher levels of atmospheric nitrogen oxides throughout the country, but especially in urban areas.

Since 2000, high concentrations of aerial particulate matter with diameters less than 10 μm (PM₁₀) are the most frequent cause of NAAQS grade II violations (that is, an average annual concentration of such particulate matter at concentrations ≤ 100 μg m⁻³). In Beijing, the annual average level of PM₁₀ fluctuated around 160 μg m⁻³ from 2000 to 2004 (Beijing EPB 2005). Megacities such as Beijing, Shanghai, and Guangzhou are frequently among the cities of the world with the highest levels of airborne particulate matter (UNEP 2002).

Large areas of China are exposed to high levels of particulate pollution (Figure 4). For example, the vast region extending from the North China plain down to the Yangtze River delta and the heavily urbanized Pearl River delta region show aerosol optical depths (AOD) of 0.6–0.8 (AOD is an index describing the absorption of light due to atmospheric particles ie the opaqueness of the air). In contrast, the AOD for Europe measures between 0.5 and 0.1 for industrialized and rural areas, respectively (Gonzales *et al.* 2000). A study of 30-year variations of atmospheric AOD in China showed that

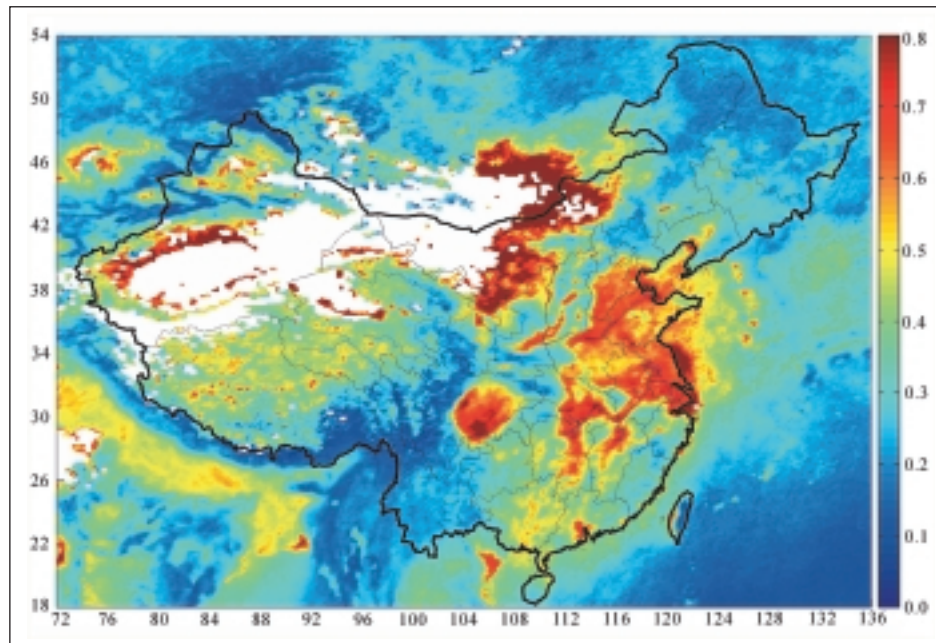


Figure 4. Distribution of aerosol optical depth over China in 2002 (Li *et al.* 2003).

levels increased by 9.5% from 1970 to 1979 and by 21.8% from 1980 to 1989 (Luo *et al.* 2002).

In recent years, the “gray sky” phenomenon has been the subject of growing public concern (Figure 5). Research shows that high levels of ambient fine particles (PM_{2.5}, ie airborne particulate matter with diameters less than 2.5 μm) lead to poor visibility (Song *et al.* 2003). In 2001, the concentration of PM_{2.5} in Beijing averaged 110 μg m⁻³, more than seven times the ambient air quality standard recommended by the US Environmental Protection Agency for fine particulate matter (Wang *et al.* 2004). Fine particle pollution in urban areas poses a serious health risk to residents, but particularly to individuals who suffer from respiratory ailments, the elderly, and children (Zhang *et al.* 2002; Li *et al.* 2005). Such severe fine-particle pollution is seldom observed in developed countries.

The very high PM_{2.5} levels are most probably the result of secondary particle production due to chemical reactions in the atmosphere. Ground-level ozone (a typical component of photochemical smog) is formed by the reactions of NO_x and volatile organic compounds (VOCs) under solar radiation (Haggen-Smit 1952). Areas of elevated fine particulate concentrations can also form downwind of the precursor source areas if there is considerable movement of air. More importantly, atmospheric oxidation capacities are enhanced by increasing O₃ concentrations (Wennberg *et al.* 1998). Thus, SO₂, NO_x, and volatile organic compounds will be transformed into fine particles (ie PM_{2.5}) more efficiently where O₃ concentrations are higher due to increased rates of oxidation.

High concentrations of ground-level ozone have been observed for many years in China's urban areas. For example, researchers at Peking University measuring the diurnal variations of episodic ground-level ozone in

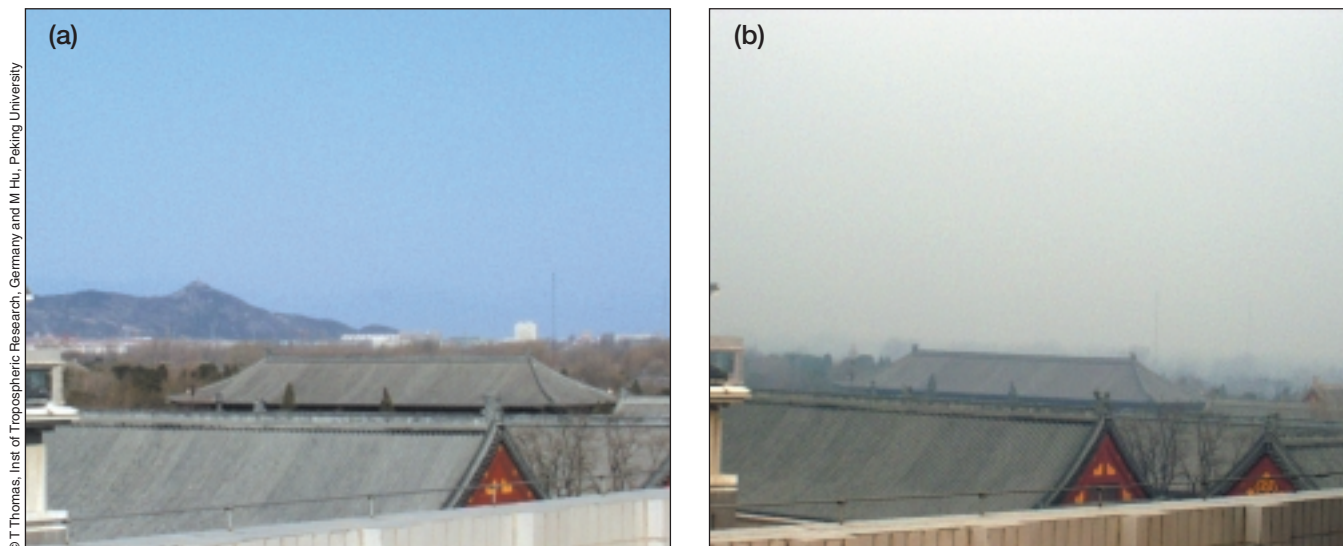


Figure 5. Photographs of Beijing, taken from the top of a building on the campus of Peking University, (a) on a clear day and (b) on a hazy day.

Beijing from 1982 to 2003 found that O_3 concentrations have increased sharply since the 1990s, and often exceed 200 ppb (Figure 6). A similar study in the Yangtze River delta region showed that high ozone concentrations are also often found at sites some distance removed from urbanized or industrial regions (Wang et al. 2005).

Such high levels of both primary and secondary airborne pollutants lead to the development of a (perhaps typically Chinese) “air pollution complex” concept (Figure 7). The main purpose of the air pollution complex model is to underscore the variety of interactions of airborne pollutants in China: how increased atmospheric oxidation capacity, caused by the formation of ozone, will speed up

the conversion of SO_2 , NO_x , and VOCs into sulfates, nitrates, and particulate organic matter, and how these fine particles, in turn, play a catalytic role in further heterogeneous reactions (Ravishankara 1997). While it is true that these processes are observed in many locations around the world, the conditions prevalent in China – high concentrations of SO_2 , oxidants, and their precursor components, as well as the comparatively high concentrations of suspended particles, etc – result in a level of aerial chemical interactions that is probably unique to the country.

In recent years, intensive efforts have been made to reduce air pollution in China. Countermeasures, such as adapting energy production (including shifting primary energy production from coal to gas), reducing sulfur emissions through increased use of low-sulfur coal and fuel gas desulfurization, and promoting more stringent vehicular emission standards as well as switching to non-leaded gasoline, have been implemented in urban areas throughout the country. These measures have, to some extent, slowed the rate of increase of pollutant emissions (Figure 8). Nevertheless, while these measures might be effective for the abatement of some primary pollutants, they are insufficient for the control of secondary pollutants and the resulting chemical interactions that form the core of the air pollution complex model.

The pollution complex concept might also be applicable to water pollution, in view of the interactions between aqueous pollutants (eg metals, nitrogen, and organic material) and the interfaces among water, sediment, and aquatic organisms. Furthermore, exchange of

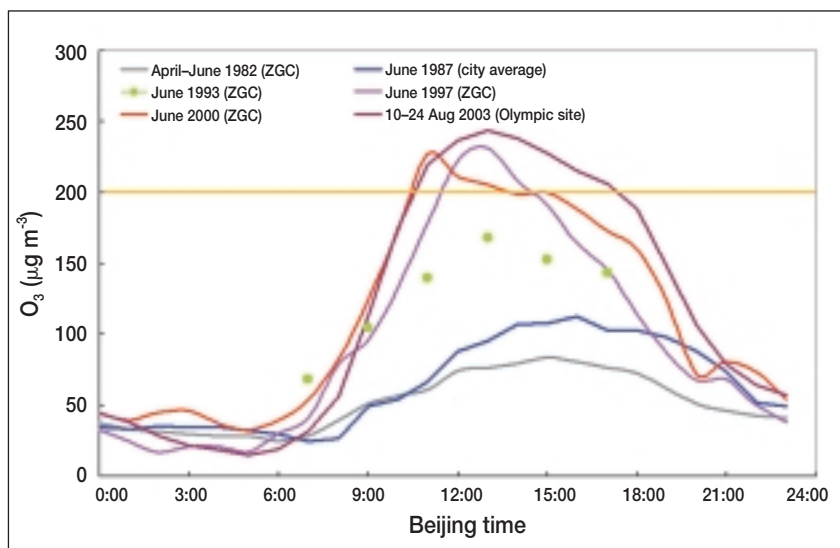


Figure 6. Trends in the episodic concentrations of ambient O_3 measured in Beijing from 1982 to 2003 in Zhongguancun (ZGC), a northwest suburb of the city, about 20 km of Tian’anmen square. The 2008 Olympic Games site is about 4 km north of ZGC. The yellow line indicates the 1-hour average O_3 concentration at grade II, according to the national ambient air quality standards of China (2000 amendment to GB3095-1996).

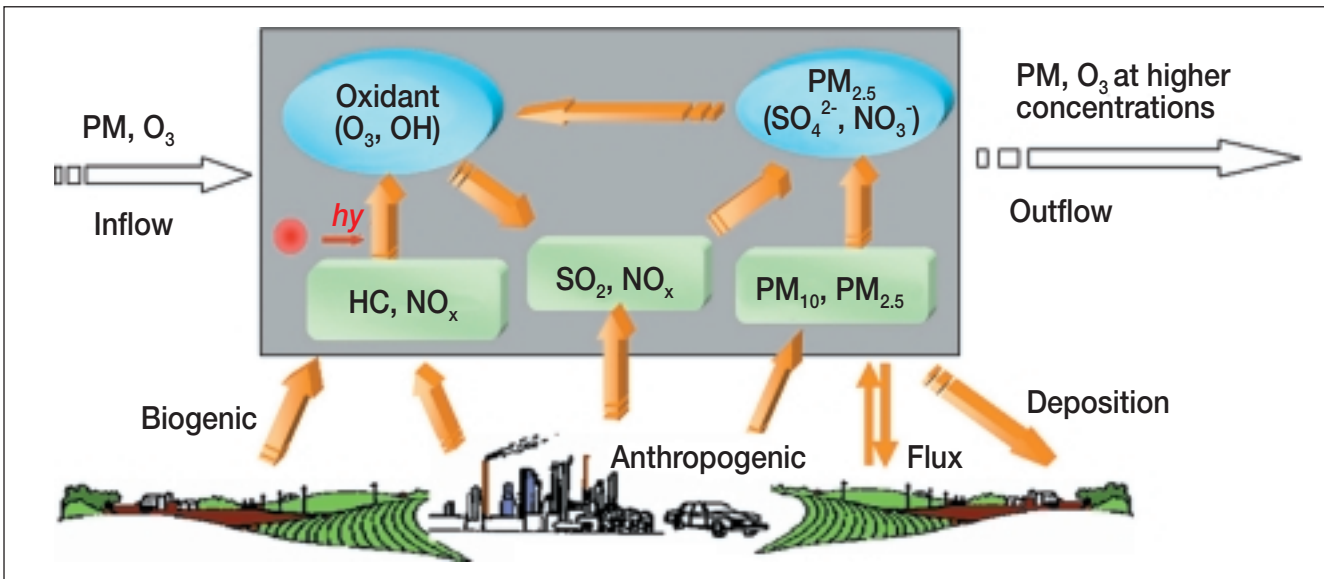


Figure 7. “Air pollution complex” concept in a Chinese city cluster.

materials between the atmosphere, pedosphere, and the terrestrial and aquatic ecosystems (eg the nitrogen cycle) links air, water, and soil pollution together, suggesting that the control of the pollution complex requires an integrated approach. While abundant expertise from Europe and the US is available to address pollution problems (such as photochemical smog, acid deposition, and suspended particles), the knowledge and experience needed to find solutions to the unique pollution complex in China are still lacking.

■ Challenges for future development

The Chinese Government has set as a goal the doubling of the country’s GDP (using 2000 as the baseline) by 2010, and quadrupling it by 2020. As a result, each province and city, from the coastal areas to the western parts of China, has created its own economic development plans accordingly. A new round of rapid economic development is therefore expected to spread across the country. More city clusters will be generated as a result, and the natural environment will be subjected to even greater stress.

If, by 2020, 50% of China’s population live in towns and cities, domestic water needs will be double those of 2000, while industrial use will increase 1.5 times (Peng 2002). As water consumption rises, so too will the amount of discharged domestic sewage, by a factor of at least 1.3 (Han 2004). Should effective countermeasures not be taken,

China’s already fragile freshwater ecosystems will come under even greater strain.

Low energy efficiency is one of the main causes of air pollution in China. Currently, the nation is one of the world’s biggest consumers of energy and materials, but is very inefficient in the use of these resources (Imhoff *et al.* 2004). While China’s GDP accounted for only one-thirtieth of the total global GDP, raw material consumption rates were much higher; for instance, China’s steel, coal, and cement consumption accounted for 25%, 33%, and 20% of world totals, respectively (Guo 2004).

The increase in vehicular traffic is another main cause of air pollution. China is anticipating a threefold to sevenfold increase in the number of motorized vehicles between 2002 and 2020. It is projected that CO₂ emis-

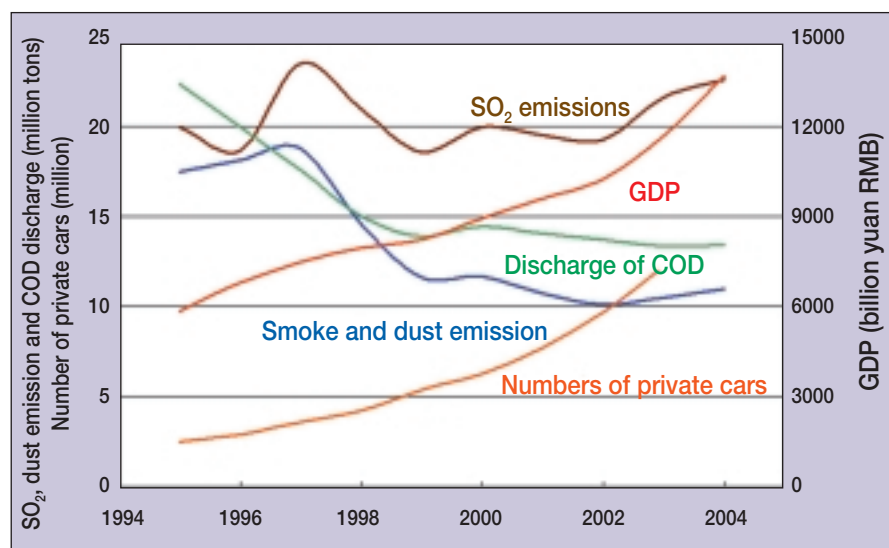


Figure 8. GDP, number of cars, and emission of SO₂, smoke and dust, and discharge of COD in China, 1995–2004. (Data on GDP and private cars from the National Bureau of Statistics [1995–2004]; data on emissions of SO₂, smoke and dust, and COD discharge from SEPA [1995–2004].)

sions from motor vehicles will quadruple during the same period, carbon monoxide and hydrocarbon levels will triple, and NO_x and PM levels will also remain at high levels (CAE 2003).

Increasing China's already severe air pollution will substantially increase the incidence of respiratory diseases throughout the country, as air pollution is estimated to be the primary cause of nearly 50% of all respiratory ailments (Brunekreef and Holgate 2002). According to UN Environmental Programme statistics (1999), soot and particle pollution from the burning of coal causes approximately 50 000 deaths per year in China, while some 400 000 people suffer from chronic bronchitis annually in the country's 11 largest urban areas. The UN Development Programme estimated that the death rate from lung cancer in severely polluted areas of China was 4.7–8.8-fold higher than in areas with good air quality (UNDP 2002). Extrapolating from current emission levels and trends, the World Bank estimated that by 2020 China will need to spend approximately US\$390 billion – or about 13% of projected GDP – to pay for the health-care costs that will accrue solely from the burning of coal (World Bank 1997).

A recent study on sustainable energy strategies for China indicates that by means of improvements in energy efficiency and some restructuring, the projected quadrupling of the country's economy would require only a doubling of current energy consumption rates (Zhou 2003). Implementing sustainable energy strategies will greatly improve China's energy efficiency by 2020, and CO₂ emissions, remaining high in terms of emissions per unit GDP when compared with other countries, will be greatly reduced as well.

It is now widely accepted in China that the course of economic development projected to occur over the next 20 years must avoid the pitfalls of high energy and resource consumption, widespread pollution, and the low rates of return that characterized the expansion of the Chinese economy over the previous 20 years. The World Bank and the Global Environment Facility have financially supported the development of three Energy Management Companies (EMCs) in China, and this has helped to identify and eliminate energy inefficiency, but a similar approach is needed for the conservation of water and other natural resources as well. To realize this goal, laws and regulations promoting a cyclical economy must be introduced, so that producers, consumers, governmental organizations, and the media all bear social responsibilities equally. Greater investment in the technologies that would promote a cyclical economy is also required, including technologies for the re-utilization of industrial and agricultural waste material. Finally, education programs designed to increase public awareness concerning current environmental issues and the incorporation of resource conservation into economic planning are essential for China's future development.

■ Conclusions and suggested strategies

China's economic growth over the past 20 years has brought many benefits to its citizens, but at the cost of an exponential increase in pollution over a relatively short time (Liu and Diamond 2005). City clusters, where both economic activity and large populations are concentrated, suffer from extensive environmental degradation. China's unique pollution complex, characterized not only by high levels of primary pollutants but also by the interactions between them, and by their spread from source locations, leads to complicated regional problems. The large-scale watershed pollution and air pollution complex will continue to worsen if stringent measures to protect the environment are not taken soon.

The realities of both economic losses and increasing mortality rates due to pollution have prompted a very serious consideration of future developments, and as China enters into a new phase of development and economic prosperity, it finds itself at a crossroads. Will the country continue down the same road as in the past two decades, or will environmental quality, energy efficiency, and the conservation of resources no longer be sacrificed at the altar of economic development?

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