

China's environment: challenges and solutions

With 1.3 billion citizens, China is the most populous country in the world. Roughly one out of every five people lives in China, a relatively poor nation with scarce natural resources. The country's per capita gross domestic product (GDP) in 2004 was estimated at roughly US\$1200, only one fifth of the world average, and much less than that of developed countries (eg US\$39 496 for the USA and US\$29 906 for Japan). China's per capita quantities of forest and fresh water are only one-sixth and one-fourth of the world average, respectively, and its petroleum and natural gas resources are also very poor. Half of its territory has an arid or semi-arid climate and about three-quarters of the country is covered by mountains. Despite this, China is currently experiencing remarkable economic growth, averaging an annual GDP growth rate of 10% over the past two decades.

With this dramatic economic development and the accompanying population increase, China's environmental problems, including energy and water shortages, water and air pollution, cropland losses, desertification, and biodiversity losses, have become severe, and are obstacles to the sustainable development of the country.

The Chinese Government is focusing on these environmental problems and has implemented a series of initiatives to ameliorate them (eg the Three-North Protective Forest Program, the Natural Forest Conservation Program, and the Wetland Restoration Program). Some of these initiatives have already begun to take effect: the reforestation projects have not only increased forest cover and prevented soil erosion, but also function as significant sinks for atmospheric CO₂, and the Wetland Restoration Project is beginning to restore wetland biodiversity. However, large hydroelectric projects, such as the ongoing development of the Three Gorges Dam, are expected to have severe ecological consequences.

Economic and social development is essential to eradicate poverty, and sustainable development depends on environmental protection. Thus, economic development and environmental protection must reinforce each other. The key to sustainable development lies in knowing how to manage the trade-offs between the two. Ecological science must play a prominent role in the harmonization of these relationships, and is particularly critical in China.

In order to understand China's environmental problems, to explore possible solutions, and to provide policy makers with recommendations on how to solve these problems, we have organized this special issue of *Frontiers*, which will discuss some of the most far-reaching environmental issues in China today. Zhao *et al.* (pp 341–46) provide evidence of the ecological consequences of the urbanization processes in Shanghai from the mid-1970s to 2005. China is one of the world's "mega-biodiversity countries", but has suffered severe degradation due to a long history of agricultural exploitation; Tang *et al.* (pp 347–52) document the importance of mountains in protecting China's biodiversity. China's rivers, lakes, and seas are also experiencing serious environmental degradation, and the deficiency of water resources has seriously hampered the country's economic development. Shao *et al.* (pp 353–61) review the history and current status of water and air pollution caused by city clusters, while Yang and Pang (pp 362–68) discuss the implementation of "China's Water Agenda 21", which was formulated to solve China's water shortage problems. Fang *et al.* (pp 369–77) present an overview on the changes in aquatic diversity in the Central Yangtze region over the past 50 years. Finally, An and Hu (pp 378–86) report on their investigation of endocrine disrupting chemicals in China's aquatic environments, finding high concentrations in seawater along the coasts and in sediments of major rivers. Although these papers do not encompass all of the important environmental issues in China, they do highlight some of the most pressing problems.

China's extraordinary rate of economic development makes it a historically unique, grand-scale socioeconomic and ecological "experiment". No one knows what the future holds, but there is no doubt that the experiment will have an unprecedented impact, not only on the country's own environment and that of its neighbors, but on the world as a whole. Minimizing these adverse environmental impacts is a great challenge and will require the concerted efforts of decision makers, academics, non-governmental organizations, and the public worldwide.



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China's environmental health challenges



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China's rapid economic growth has generated high levels of water and air pollution, subjecting both the Chinese themselves, and broader populations, to significant health risks (*Nature* 2005; **435**: 1179–86). A recent update (www.healtheffects.org/Asia/papasan-home.htm) to a review of the Asian scientific literature on air pollution and health conducted by the Health Effect Institute's (HEI) Public Health and Air Pollution in Asia Program (HEI 2004. Special Report 15. Boston, MA) found over 120 studies, carried out in Chinese cities, documenting links between exposure to air pollution and increases in respiratory symptoms, hospitalization, and premature mortality. The World Health Organization (WHO) has estimated that current air pollution levels could be responsible for over 300 000 premature deaths in China annually (The World Health Report 2002. Geneva, Switzerland: WHO). These effects extend beyond China's borders; pollution generated in China is transported to neighboring countries (eg Japan and Korea), as well as over much greater distances, contributing to health impacts in those countries as well. Pollution can also facilitate and/or exacerbate infectious diseases that have their origins in Chinese and other Asian cities, as a recent analysis of the impact of air pollution on the mortality rate from SARS suggests.

China's economic progress, however, can be the foundation of both improvements in environmental health for China and a model for the developing world. Economists have described the economic pattern of increasing economic growth as resulting first in increased pollution but then, as resources improve, in investments in environment enhancement (*Econ Hist Rev* 1995; **48**: 643–64). In the area of vehicle emissions, China has already made progress, becoming one of the first developing countries to remove lead from fuel, and adopting stringent fuel efficiency and European auto emission standards at a pace faster than Europe or the US. A recent study in Hong Kong documented the measurable benefits, in terms of reduced mortality, resulting from a substantial reduction in sulfur in fuel (*Lancet* 2002; **360**: 1646–52).

China has identified the upcoming Beijing Olympics as a signal opportunity to both achieve environmental improvements and to document that progress on a world stage. There are also major economic opportunities in developing the expertise and production capability for pollution control technologies that can serve to address China's own needs while at the same time positioning the country to become a lead exporter of these technologies to other countries in Asia, which also face the need to clean up their environment.

Thus, although China currently faces considerable environmental challenges, its growing economic ability to invest in environmental improvement may provide important opportunities for China and the globe.

Impacts of China's air pollution



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China is still a developing country, although a different impression may be had by visiting one of its booming major cities. Chinese people seem to work day and night, 7 days a week, and China is the only industrial region on Earth which doesn't show the "weekend effect" – the lower concentrations of NO₂ detected by satellites on the weekend as compared to workdays.

China's current air pollution situation can be compared to that of Western Europe in the 1960s. Industrialization is proceeding rapidly and gross national product is growing by almost 10% per year. Even so, China's per capita energy use is only a ninth of that of the US. Substantial parts of the country are already highly polluted, a situation which may well worsen in the future. Despite the relatively low per capita energy use, its large population means that China is already the second biggest energy consumer in the world, while emissions of SO₂ are the highest in the world, due to the burning of fossil fuels. As a result of the growing number of automobiles, emissions of NO_x and hydrocarbons are also increasing, leading to greater concentrations of ozone.

The impact of China's industrial and agricultural emissions on climate is difficult to assess. On the one hand, emissions of CO₂ from burning fossil fuels, and of methane from coal mining and animal husbandry, have a warming effect on climate. However, the high emissions of SO₂ and consequent sulfate particle formation will lead to a cooling climate. Here we hit a dilemma. Because of negative health effects, emissions of air pollutants, especially SO₂, will have to decrease in future. Paradoxically, however, this will lead to a warmer climate. (Reductions in the emission of soot will have the opposite effect). Thus, in the future, China (as well as other countries) will have a double heating effect on earth's climate, (a) by enhanced emissions of CO₂ and (b) by reducing the aerosol loadings of the atmosphere. This is due to greater reflectivity of sunlight back to space, which also leads to higher cloud albedo by increasing the number and concentration of cloud droplets which condense on the sulphate aerosol particles. All these factors are important for earth's climate and air quality.

With its rapid industrial development, it is important that China focuses strongly on environmental issues. As its environmental footprint is bound to increase, greater environmental research efforts and international collaborations are of the utmost importance.