

# COMMENTARY

## China's Mercury Problem: A Sleeping Giant?

By Celia Y. Chen

*Baiyangdian Lake in Hebei Province is intensively utilized and altered by humans. This freshwater system, like many in China, suffers from contaminant inputs from industry, nutrient inputs from agriculture and aquaculture, and fish kills due to anoxia and lake drying. In 2001, we collaborated with Chinese scientists to investigate metal contaminants in the lake with particular interest in methylmercury, a potent neurotoxin to which humans throughout the world are increasingly exposed, mainly through consumption of fish and shellfish (Mergler, et al., 2007; Rice et al., 2000; Sunderland, 2007). Human exposure to mercury is of particular relevance to China given the country's major emissions of Hg from coal-fired plants and the dependence of its population on freshwater fish for protein.*

In China, populations are exposed to mercury in areas where fish is a primary food source, through ingestion of contaminated rice, or occupational exposures to mercury via inhalation, usually in coal mines. Mercury in the environment is found in inorganic ( $\text{Hg}^{2+}$ ) and organic (methylmercury) forms of which the latter is the most toxic and readily accumulated in humans and wildlife. Concentrations of mercury in fish are predominantly methylmercury and consumption of fish is the main vector to humans. Mercury concentrations in commonly consumed freshwater fish species in China exceed the maximum allowable limit in fish recommended by the World Health Organization (0.4 mg per kg wet weight) posing a threat to human health (Jin et al., 2006; Chen et al., 2008). These elevated mercury exposures are directly related to the high levels of mercury emissions and deposition in China largely from coal burning and mining that end up in the country's agricultural crops and aquatic food chains. Moreover, reservoir construction for hydroelectric power in China may also exacerbate the levels of mercury bioaccumulating in reservoir fish.

### HUMAN HEALTH DANGERS FROM MERCURY

Human exposures to methylmercury have resulted in neurological and cardiovascular effects in adults

and developmental effects in children (Grandjean et al., 2005; Mergler et al., 2007). *In utero* exposures are also linked to neurobehavioral problems in children (Grandjean et al., 1997). Thus, children and the unborn fetus (exposed via pregnant mothers) are considered to be the populations at greatest risk of mercury exposure and toxicity (Oken et al., 2005). There are documented cases of mercury exposure in China that have been linked to neurological and physiological effects. For example, a recent study in the city of Changchun in Jilin Province revealed that fish consumption is the primary route of exposure (43 percent of the absorbed dose), followed by inhalation of mercury from coal burning and ingestion of cereal and grains (Li, Wang & Luo, 2006). Fish consumption is also related to elevated blood and hair mercury levels in children living near the South China Sea (Ip et al., 2004). In the industrial port city of Tianjin, mercury is the major risk contributor for children of all the heavy metals measured—copper, zinc, lead, cadmium, mercury, and chromium—due to ingestion of vegetables and fish (Wang et al., 2005). In Guangzhou median blood mercury levels in children were ten times higher in 2001 and 2002 than those of children in the United States (Ye, Fu & Guidotti, 2007).

In certain regions of China, mercury contaminated rice is also an important exposure route (Feng et al., 2008; Li et al., 2008). Fish and rice are both impor-

## Estimates of mercury emissions identify Asia as the source of 54 percent of global emissions with China contributing 28 percent of the total.”

tant components of Chinese diets and thus potential vectors for mercury-human exposure. Although ceasing fish consumption in some exposed populations in China has resulted in a reduction in mercury hair and blood levels (Ip et al., 2004; Weihe et al., 2005), this is not necessarily an optimal strategy for reducing health risks. Fish consumption is an important source of protein for many populations around the world and often the main source of important omega-3 fatty acids, which some studies have linked to benefits in neurological development and diminished risks of cardiovascular disease (Oken et al., 2005; Budtz-Jorgensen et al., 2007).

Studies documenting human health outcomes of mercury are fewer in China, but indicate health effects in exposed populations:

- High levels of fish consumption and methylmercury exposure have been correlated with male infertility in Hong Kong (Dickman, Leung & Leong, 1998; Dickman & Leung, 1998).
- Artisanal mercury mineworkers in Wuchuan County (Guizhou Province) with methylmercury exposures via inhalation and rice consumption were found to exhibit clinical symptoms (eyelid tremors and gingivitis) of mercury poisoning (Li et al., 2008a & 2008b).

### A LONG-TERM PROBLEM: PERSISTENCE AND BIOACCUMULATION IN THE ENVIRONMENT

Fluxes of mercury into the atmosphere from anthropogenic sources have increased substantially with industrialization, increasing the mercury concentrations in foods that humans consume (Mason, Fitzgerald & Morel, 1994). Throughout the world, mercury is now present in fish and shellfish at lev-

els that can adversely affect humans and wildlife (Driscoll et al., 2007; Evers et al., 2007). The ultimate exposure of humans to methylmercury results from four steps in the environmental fate of mercury:

- (1) Emission of inorganic mercury from coal combustion and metal smelting;
- (2) Deposition of inorganic mercury on the landscape;
- (3) Transformation of inorganic mercury to Methylmercury in aquatic systems; and,
- (4) Bioaccumulation of methylmercury in fish and shellfish.

Anthropogenic sources (e.g., electric utilities, incinerators, and industrial facilities) emit inorganic mercury ( $Hg^0$  and  $Hg^{2+}$ ) into the atmosphere where it is transported and eventually deposited on the landscape (Wiener et al., 2006; Driscoll et al., 2007). Inorganic mercury is then transported via streams and rivers to lakes, reservoirs, and coastal systems where sediment microbes transform it into methylmercury. Methylmercury—the most toxic and bioavailable form of mercury—is readily bioaccumulated and biomagnified in aquatic food webs where it reaches concentrations of potential risk to humans and wildlife. Reservoir creation and management practices have been shown to contribute to higher levels of methylmercury bioaccumulation in fish. In fact, methylmercury bioaccumulation is greater in reservoir fish associated with hydroelectric power than in natural lakes (Tremblay, Cloutier & Lucotte, 1998; Schetagne & Verdon, 1999; Mailman et al., 2006). Thus, increased exposures of humans to methylmercury are attributable to mercury emission and transformation processes related to two of the most common modes of electricity production: coal combustion and hydroelectric power.

### SOURCES OF MERCURY

Globally about two-thirds of the total global emissions of mercury stem from combustion of fossil fuels, most of which is coal combustion. Estimates of mercury emissions identify Asia as the source of 54 percent of global emissions with China contributing 28 percent of the total (Pacyna et al., 2006; Jaffe & Strode, 2008). Mercury emitting industries such as steel production, gold mining, and electrical and electronic manufacturing also have domi-

nated industrial development in Asia (Wong et al., 2006). China emitted 696 tons of mercury in 2003 increasing at an average annual rate of 2.9 percent from 1995 with 80 percent of those emissions coming from coal combustion and nonferrous metal smelting (zinc, lead, copper and gold; Wu et al., 2006). In Guizhou Province—a particularly well-studied mining region in China—mercury emissions increased approximately 3 times from 1986 to 2002 and are estimated to double again by 2015 (Tang et al., 2007). China's increase in emissions will undoubtedly increase the global atmospheric pool of mercury as well as the local deposition of mercury domestically with direct consequences for the Chinese population.

## HIGH LEVELS OF MERCURY DEPOSITION

In China and other parts of the world, local sources of mercury deposition result in elevated levels in nearby soils and water bodies (Horvat et al., 2003; Wang et al., 2005; Zhang et al., 2006; and Evers et al., 2007). Studies in the northeast United States have shown that mercury deposition in any given region is from both long distant transport and local sources (Evers et al. 2007). In China, estimates of emissions and transport indicate that most of the inorganic mercury emitted by coal-fired plants, metal smelters, and other industries is deposited within China (Jaffe et al., 2008). This suggests that mercury deposition on the local landscape is a major repository of China's own industrial emissions. In fact, air mercury concentrations in Wuchuan, Guizhou Province, one of the important mercury production centers in China, are 100 to 10,000 times higher than background concentrations in Europe and North America (Horvat et al., 2003; Wang et al., 2007). In Beijing and Tianjin, mercury decreases with distance away from the city center into the suburbs suggesting that there is a local deposition of fly ash emitted from power plants (Wang et al., 2005; Zhang et al., 2006). Humans in these areas of high deposition are particularly vulnerable to mercury exposure via inhalation and ingestion of foods (e.g., fish and rice) in which methylmercury has bioaccumulated.

## ENERGY PRODUCTION AND MERCURY IN CHINA

China is expected to quadruple its gross domestic product and double its energy use between 2001 and 2020 (Yonghul et al., 2006). This is being met

by a surge in construction of energy production facilities, predominantly coal-fired power plants and hydroelectric dams. By 2015, an additional 562 coal-fired power plants will be constructed in China to total more than all the coal-fired power plants in the United States and Europe combined (Dickinson, 2007). China's coal use is expected to increase by 4 percent each year resulting in increased emissions of CO<sub>2</sub>, SO<sub>2</sub>, and mercury.

Large dams are being constructed throughout Asia as a way to meet growing energy demands while using renewable energy technologies. China's hydroelectric power capacity is growing rapidly with plans to produce 200-240 GW of hydroelectricity by 2020 (Jing, 2006). This near quadrupling of current hydropower will be roughly the equivalent of building one Three Gorges Dam (which inundated an area of 632 km<sup>2</sup>) every two years (Yonghul et al., 2006). In fact, although half of the world's largest dams are in China, most of the country's hydroelectric potential has yet to be exploited (Sweet, 2001). These new dams will flood large areas of agricultural and forested land creating large areas of mercury methylation—transforming inorganic mercury to methylmercury the toxic form—in reservoir sediments and bioaccumulation of methylmercury by fish.

### Impacts of Reservoirs

Hydroelectric reservoirs are known “hotspots” for elevated methylmercury bioaccumulation in fish. When soils that contain mercury deposits from industry are submerged due to flooding in the creation of reservoirs, there is an initial transformation and release of methylmercury into the water and a subsequent bioaccumulation of methylmercury in the aquatic food chains (Anderson et al., 1995; Schetagne et al., 1999; Evers et al., 2007). Studies in Canada and elsewhere have also shown that elevated mercury in reservoirs arises from fluctuations associated with management (e.g., raising and lowering water levels). Elevated mercury levels have been found to remain high for up to 21 years in fish (Anderson et al., 1995; Schetagne et al., 1999). Total mercury concentrations in aquatic organisms increase 1.5 to 4 times natural lake background levels in new reservoirs and methylmercury concentrations increase by 30 percent in the first 13 years after reservoir creation (Tremblay et al., 1998; Schetagne et al., 1999; Mailman et al., 2006).

In the northeast United States, many reservoirs have considerable methylmercury bioaccumulation in fish due in part to the degree of water level



In the intensively utilized Baijiangdian Lake in Hebei Province, some fish species caught by fishers contained mercury at levels exceeding U.S. EPA human health screening values. Photo Credit: Paul Pickhardt

fluctuation. Reservoirs with greater fluctuation contain fish with higher mercury concentrations (Rodgers, Dickman & Han, 1995; Evers et al., 2007). A study of 12 reservoirs in China revealed that reservoir carp had consistently higher mercury concentrations than carp in the adjacent rivers and that fish from reservoirs with larger catchments and flooded areas had higher mercury concentrations (Jin, Hui & Xu, 1999). This suggests that populations harvesting fish from the reservoirs in China will be at increased risk of mercury exposure.

### **FINAL THOUGHTS ON MERCURY RISKS IN CHINA**

The combination of increased mercury emissions and deposition on the landscape in China with the increased land areas being converted to reservoirs will undoubtedly result in more methylmercury exposure to the Chinese population, primarily through consumption of fish. The extent of the increased human exposure will depend on how well these aquatic systems will be monitored for mercury and whether fish consumption advisories are

established, publicized and understood by Chinese consumers. To date, though research on mercury emissions has been increasing in China, mercury bioaccumulation in fish and human exposures via consumption of fish have received far less attention. The mercury in water issue is perhaps overshadowed by the greater news media attention of toxic algal blooms and major pollution accidents into China's lakes and rivers. Sleeping giants rarely make headlines. However, mercury is likely to be far more widespread and its effects more insidious than other pollution problems in China.

In our study of Baiyangdian Lake, we found that there were some fish species caught by fisherman destined for market with mercury concentrations exceeding U.S. Environmental Protection Agency human health screening values (Chen et al., 2008). There is great potential for major influxes of methylmercury into fish due to the high mercury deposition in China and the extensive creation of hydroelectric dams and reservoirs. These energy production developments could result in a major human health issue, and should be brought to the attention of populations with the greatest potential for exposure. Steps

should be taken to monitor mercury in fish species commonly consumed particularly from lakes close to sources of mercury emissions (e.g., power plants and metal smelters) and in reservoirs. Such monitoring would provide some minimal information for fish consumption advisories that would begin to protect public health in this rapidly developing country.

*Celia Chen is an aquatic ecologist who has conducted research on the fate and effects of toxic metals in aquatic ecosystems over the last 13 years. She has specialized in the study of mercury bioaccumulation and trophic transfer in lake and reservoir ecosystems. Her research has covered much of the Northeast United States and also Baiyangdian Lake in Hebei Province, China. This research has been supported by grants from the Superfund Basic Research Program of NIEHS (NIH Grant Number P42 ESO737) and the Strategic Environmental Research and Development Program of DOD. She can be reached at: celia.chen@dartmouth.edu.*

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# SPOTLIGHT

## Greening China's "Factory of the World:" Institute for Sustainable Communities in Guangdong

By Zhang Ye

China's Guangdong Province helped spur the nation's economic miracle and continues to remain a powerful engine of growth, generating 11 percent of the nation's gross domestic product. At the same time, the province faces frequent energy shortages and deteriorating environmental conditions. In response, the Chinese central government set ambitious environmental, health and safety targets, as well as standards for energy use and intensity. However, due to its large number of factories, Guangdong's compliance with these regulations lags behind those of other regions.

In order to help factories achieve and move beyond compliance, the Institute for Sustainable Communities (ISC) has developed an Environment, Health, and Safety (EHS) Academy that will expand the number of qualified EHS managers serving enterprises in Guangdong, a region that has become known as the "factory of the world."

Located at Lingnan University, College of Sun Yat-Sen University in Guangzhou, the academy marks the first time Chinese and U.S. experts have joined together to create a world-class, independent, Chinese-owned and Chinese-staffed EHS training center. Through affordable and convenient training, managers will learn to apply international best practices in EHS management, enabling their companies to increase compliance with Chinese standards, lower energy consumption, and reduce greenhouse gases and other harmful emissions.

ISC developed the academy concept over the course of two years through hundreds of meetings and consultations with Chinese government agencies, factory managers, and multinational corporations. At a 2006 seminar organized by ISC and the General Electric Company, corporations concluded that the most cost-effective way to improve EHS performance within their supply chains—and across Guangdong's manufacturing sector—was to expand the number of EHS managers, or "cham-

pions," with the practical knowledge, management expertise, and leadership skills needed to produce positive change in their factories.

The EHS Academy curriculum is based on training developed by leading multinational corporations and international and Chinese experts. A project steering committee made up of ISC's key corporate and Chinese partners provides oversight and guidance. A core group of master trainers began training EHS Academy trainers in early 2009, and ISC anticipates enrollment for the fall session will begin mid-year. The academy aims to certify several thousand managers in its first three years of operation.

The greening of Guangdong's supply chain through the creation of the EHS Academy serves as a strategic approach to promoting sustainable business practices—achieving healthier communities. The academy will serve as a permanent source of EHS leadership and expertise in south China. In this way, it represents a departure from the traditional approach of auditing suppliers. ISC's approach will build the capacity of Chinese practitioners to meet and exceed international practices—and to actively contribute to the growth of the EHS profession in China.

ISC plans to measure results by tracking a number of indicators, including material environmental compliance findings in EHS audits, as well as measures taken to meet international standards. ISC will also measure the reduction of energy consumption at the same level of output, and the reduction of greenhouse gases and other pollutants.

The EHS Academy is a public-private partnership funded by ISC's corporate partners—the GE Foundation, Citi Foundation, Honeywell, and SABIC Innovative Plastics—as well as by the U.S. Agency for International Development. More companies are expected to join the partnership. Resource partners include GE, Adidas,



Workers make tiles in a ceramic factory in Guangzhou, China. ISC is helping factories improve energy efficiency, reduce greenhouse gas emissions, and protect worker's health by launching an academy to train managers on environment, health and safety standards. Photo Credit: Matthew DeGroot

Business for Social Responsibility, U.S.-China Business Council, and the Natural Resources Defense Council. Chinese partner agencies include the Guangdong Economic and Trade Commission, the Guangdong Bureau of Work Safety, and the Guangdong Environmental Protection Bureau.

The EHS Academy is part of a larger ISC program to improve environmental health and resource efficiency in Guangdong. ISC also works with local

and regional authorities to improve environmental governance, with educators to develop and implement courses on sustainable development that will provide hands-on learning to primary and middle school students, and with municipal districts and townships to demonstrate how communities can design and implement comprehensive energy efficiency programs.

*For more information, please visit [www.iscot.org](http://www.iscot.org) or contact Zhang Ye at: [zhangye@iscchina.org](mailto:zhangye@iscchina.org).*



# COMMENTARY

## Public Health and Air Pollution in Chinese Cities: Local Research With Global Relevance

By Sumi Mehta, Aaron J. Cohen, Davida Schiff, Daniel Greenbaum,  
Nick Moustakas, and Robert O'Keefe

As China continues to experience rapid increases in industrialization, urbanization, and vehicularization, there has been widespread awareness about the potential health impacts of air pollution. This was clearly evident as local officials in Beijing, responding to concerns raised around the world, took drastic measures to improve air quality during the 2008 Summer Olympic Games by limiting automobile traffic, suspending polluting enterprises across northern China, and reducing emissions from coal-fired power plants. These measures likely contributed to improved Beijing air quality in the short term, as Beijing's average daily air pollution index (API)—a summary indicator of air pollution—during the first 26 days of August was 36 percent lower than the average API during the same period from 2000 to 2007. In the long term, however, emission trends (e.g., energy, fuel, and vehicle use), population trends (degree of urbanization, urban population growth, and city size), health trends (age structure and background disease rates), and other important factors (broad changes in regulatory approaches and improvements in control technology) will continue to influence the extent to which exposure to air pollution affects the health of the Chinese population.

The World Health Organization estimates that urban air pollution contributes to approximately 800,000 deaths and 6.4 million lost life-years worldwide each year, with fully two-thirds of these losses occurring in rapidly urbanizing countries of Asia, including China (WHO, 2002). These estimates were made using the results of U.S. studies of long-term exposure to air pollution because such studies have not yet been conducted in the developing countries of Asia, where health,

health care, exposure to pollution, and socioeconomic circumstances still differ markedly from the United States. This contributes considerable uncertainty to these and other recent estimates of health impacts of air pollution.

With the effects on air quality of recent, rapid development visibly apparent in the haze and thick clouds of pollution that often shroud many of Asia's cities and industrial areas, government decision-makers, businesses and citizens are increasingly raising concerns about the health impacts of urban air pollution. The Public Health and Air Pollution in Asia (PAPA) Program was initiated by the Health Effects Institute to inform regional decisions about improving Asian air quality to promote health. (See Box 1). The PAPA program collects and reviews research on the health effects of air pollution in Asia, supports new research, and helps the region's scientific communities build their capacity to conduct research and communicate their results effectively to key policymakers in government, industry, international lending agencies, and other stakeholders. We focus here on the China-specific aspects of our program, including the 214 Chinese studies identified in a systematic review of the peer-reviewed scientific literature on the health effects of air pollution in Asia, and HEI-funded research on the health effects of air pollution in representative Chinese cities.

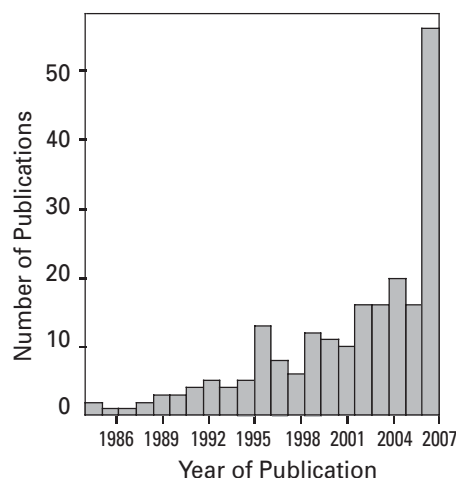
From its inception, PAPA was structured with a clear understanding that science in isolation does not effectively drive policy. We have developed effective strategies for communicating key information on the health effects of air pollution in Asian cities to policymakers and other stakeholders. This has included integrating local air pollution

**Table 1: Summary of Reports in China, 1980–2007 (By Study Design)**

STUDY DESIGN	NUMBER OF REPORTS
Case-control	7
Case-crossover	12
Cross-sectional	76
Cohort	18
Ecologic	12
Health impact	28
Panel	9
Time-series	52

Note: Data for 2007 includes only reports identified through September 2007

**Figure 1: Reports on Health Effects of Air Pollution in China 1980–2007 (By year of publication)**



Note: Data for 2007 includes only reports identified through September 2007

and health officials into the PAPA research teams in each Chinese city from the earliest stages and regular briefings of leaders from the Ministry of Environmental Protection (MEP), local environmental pollution boards, environmental nongovernmental organizations, and industry. Over the past four years, the PAPA results have also been a regular part of the annual Regional Air Quality Management (RAQM) meetings for local and national environmental officials in China that are organized in Beijing by China’s Ministry of Environmental Protection (MEP), the U.S. EPA, and European governments. These meetings address the health effects, sources of, and control measures for major pollutants in China including particulate matter, sulfur dioxide, and nitrogen oxides from industrial sources. By integrating local evidence within the global literature on the health effects of air pollution, these meetings focus on issues of particular relevance to China.

### THE HEALTH EFFECTS OF AIR POLLUTION IN CHINA: REVIEWING THE EVIDENCE

The number of published studies on the health effects of air pollution in China has been growing nearly exponentially over the past quarter

century. A total of 214 studies in China (110 in Mainland China, 25 in Hong Kong, and 79 in Taiwan) have now been identified. (See Figure 1). These account for approximately half of the studies identified in Asia overall. In addition, the consistent increase in air pollution studies in China over the past decade parallels the continued increase in similar publications within the region. This could reflect an increased awareness of environmental health risk factors in China, as well as the increased availability of data and technical capacity necessary for conducting quality health effects research. Around 35 percent of these studies are cross-sectional studies, which are typically used to study the effects of long-term exposure to air pollution on the prevalence of chronic respiratory symptoms and disease or on chronic impairment of pulmonary function. Twenty-two percent of these studies are time-series studies, which estimate the effects of short-term exposure to air pollution. Thirteen percent of the studies are health-impact assessments, which estimate the potential benefits, in terms of public health, of actions taken to improve air quality. (See Table 1). In terms of health outcomes, 43 percent of these air pollution studies focused on some aspect of respiratory disease, while 25 percent focused on mortality. (See Table 2).

Table 2: Summary of Environmental Health Reports in China, 1980–2007 (By Outcome Addressed)

OUTCOME ADDRESSED	NUMBER OF REPORTS
Biomarker	16
Birth outcomes	8
Economic assessment	18
Hospital admissions, visits, discharges	20
Lung Cancer	10
Mortality	54
Respiratory disease, symptoms, lung function, asthma	92
Other	25

Note: Data for 2007 includes only reports identified through September 2007

- **Studies in Mainland China:** Most of the reports in Mainland China described studies conducted in metropolitan areas, such as Beijing or Shanghai, or in industrial cities, such as Chongqing, Guangzhou, Lanzhou, Shenyang, or Wuhan. Some estimated the effects of exposure on the basis of residential proximity to industrial facilities or mobile sources.
- **Studies in Hong Kong:** Most of the Hong Kong reports examined the relationship between ambient pollution and respiratory symptoms and disease as well as mortality and hospital admissions. A few health-impact assessments estimated the effects of restrictions on sulfur in fuel oil and industrial air pollution.
- **Studies in Taiwan:** Half of the studies in Taiwan were conducted in the south, where petrochemical plants and heavy industrial complexes are located. More than half estimated the health effects of exposure to both particulate matter and gaseous pollutants, while the rest estimated health effects on the basis of residential proximity to petrochemical and industrial facilities and to traffic.

## FACILITATING LOCAL RESEARCH WITH LOCAL RELEVANCE

PAPA-funded studies in representative cities bridge the gap between studies conducted locally and elsewhere, and thus inform policy. These include:

### Coordinated studies in Hong Kong, Shanghai, and Wuhan on the health effects of short-term exposure to air pollution:

This is the first coordinated multi-city analyses of air pollution and daily mortality in China. Coordinated multi-city studies in Europe and North America currently provide the most definitive epidemiologic evidence of the effects of short-term exposure, and as a result play a central role in health impact assessment and environmental policy. Such studies also have provided a setting in which important analytic issues, such as how to choose among competing statistical models, can be addressed using large data sets, and can provide a context in which the local scientific capacity to conduct air pollution research can be further developed.

The PAPA studies in these three cities, which began in 2004 and concluded in 2008, are designed and conducted by local investigators in concert with local air pollution and public health officials and international experts, and examine relationships between daily changes in air pollution and mortality in cities with varying climates and air pollution levels. The studies address scientific issues of global relevance including the effects of exposure at high concentrations and at high temperatures, and the potential influence of influenza epidemics on the relationship between air pollution and health. The first systematic presentation of these results was published in the September 2008 issue of *Environmental Health Perspectives* (Kan, 2008; Qian, 2008; Wong, 2008).

For a summary of city-specific pollutant concentrations, and how they relate to WHO 2005 Air Quality Guidelines (World Health Organization, 2006), see Table 3. Note that Shanghai and Wuhan, in particular, have daily average PM<sub>10</sub> concentrations 2 to 3 times the WHO guideline levels, with a 2.5 to 5 percent increase in short-term mortality expected at the 100 and 150 µg/m<sup>3</sup> levels respectively. While Hong Kong's pollution levels appear closer to the guidelines, the standard deviations indicate that here too the guideline levels are routinely exceeded.

## BOX 1. The Health Effects Institute

The Health Effects Institute (HEI) is an independent nonprofit research institute established in 1980 to provide scientists, public and private decision-makers, and the public with high-quality, impartial, and relevant scientific information on the health effects of air pollution. Over the years, HEI has funded a comprehensive body of new research, scientific reviews, and reanalysis that were designed to be directly relevant to decisions made in the United States and in key international regulatory forums. HEI has sponsored research in the Americas, Asia, and Europe.

### PUBLIC HEALTH AND AIR POLLUTION IN ASIA—THE PAPA PROGRAM

In 2002, HEI launched the Public Health and Air Pollution in Asia (PAPA) program in partnership with the Clean Air Initiative for Asian Cities (CAI-Asia) to inform regional decisions about improving Asian air quality to promote health. The PAPA Program collects and reviews research on the health effects of air pollution in Asia, supports new research, and helps the region's scientific communities build their capacity to conduct research and communicate their results effectively to key policymakers in government, industry, international lending agencies, and other stakeholders.

### LITERATURE REVIEWS

The first external PAPA product program was an initial Review of the Health Impacts of Air Pollution in the Developing Countries of Asia (<http://pubs.healtheffects.org/view.php?id=3>) to define the existing landscape, including an initial meta-analysis of time series studies in Asia and comparison to similar studies conducted in the West. A second review, to be published in 2009, will incorporate recent research, including emerging evidence from PAPA-funded research, as well as a meta-analysis of Asian studies on the chronic health effects of air pollution.

**Public Health and Air Pollution in Asia—Science Access on the Net (PAPA-SAN)** is a web-based (<http://www.healtheffects.org/Asia/papasan-home.htm>) compendium of peer-reviewed publications of the health effects of air pollution in Asia created to help researchers studying the effects of air pollution in Asia and to provide policymakers, international lending organizations, and other stakeholders with information to help them make better-informed decisions. PAPA-SAN includes 421 peer-reviewed reports identified through September 2007 and published since 1980 on research conducted in 11 Asian countries.

### NEW RESEARCH IN ASIAN CITIES

**Time-Series Studies:** The PAPA Program has funded seven time-series studies of the health effects of short-term exposure to air pollution in China (Hong Kong, Shanghai, and Wuhan), Thailand (Bangkok), and India (Ludhiana, Chennai [formerly Madras], and Delhi). All interdisciplinary investigator teams, selected through a competitive process, consist of experienced local researchers with strong links to local health and regulatory organizations.

**Potential Asian Cohort Studies:** PAPA funded a pilot study to examine the feasibility of using an existing cohort of elderly in Guangzhou to assess the impact of long-term exposure to air pollution in the development of respiratory and cardiovascular disease. Pilot data documented the high annual levels of air pollution in Guangzhou, but unfortunately did not clearly demonstrate that large enough differences existed in exposure among the population to make a study of this cohort informative. We continue to explore the potential to fund an Asian cohort study.

**Poverty, Air Pollution, And Health:** With joint funding from the Asian Development Bank, PAPA is supporting new studies of air pollu-

tion, health, and poverty in Ho Chi Minh City, Vietnam, including a hospital-based study of acute lower respiratory infections in children and a household-based exposure assessment study. These studies attempt to address whether the poor are more exposed to and/or impacted by air pollution compared to the non-poor.

## ENSURING HIGH QUALITY RESULTS

**International Scientific Oversight Committee (ISOC):** ISOC oversees all PAPA activities to ensure scientific quality and relevance. Members are leading international experts in medicine, environmental health sciences, exposure assessment, epidemiology, and other related disciplines, including Dr. Jiming Hao of Tsinghua University Institute of Environmental Science and Engineering and Dr. Bingheng Chen of Fudan University School of Public Health.

**Quality Assurance:** PAPA's QA auditing program provides assurance to policymakers that data completeness and reliability were accurately reported by investigators. An external QA process evaluates the quality and consistency of city-specific environmental and health data and the extent to which studies are conducted according to pre-approved protocols and standard operating and quality control procedures.

**Applied Technical Assistance:** The PAPA Program is committed to building the capacity of Asian scientists and improving the quality of results. This includes intra-regional networking and assistance as well as inter-regional guidance and collaboration.

**Communicating Results:** The PAPA program continues to maintain its commitment to bring independent science about the health effects of air pollution in Asian cities to policymakers and other stakeholders, including local and national governments, civil society, academe, private sectors, and development agencies. PAPA investigators, HEI staff, and ISOC members play a visible role (including presentation of work in progress, poster presentations, and participation in symposia and/or workshops) in local, regional, and international forums.

// **In 2002, HEI launched the Public Health and Air Pollution in Asia (PAPA) program in partnership with the Clean Air Initiative for Asian Cities (CAI-Asia) to inform regional decisions about improving Asian air quality to promote health."**

Table 3: Summary of Daily Average Pollution in PAPA Time-Series Studies

AVERAGE 24 HOUR (STANDARD DEVIATION) POLLUTANT CONCENTRATION IN $\mu\text{/M}^3$					
STUDY PERIOD	PM <sub>10</sub>	SO <sub>2</sub>	NO <sub>2</sub>	O <sub>3</sub>	
Hong Kong	Jan 1996 – Dec 2002	51.6 (25.3)	17.8 (12.1)	58.7 (20.0)	36.9 (23.0)
Shanghai	Jan 2001 – Dec 2004	102 (64.8)	44.7 (24.2)	66.6 (24.9)	63.3 (36.7)
Wuhan	Jul 2000 – Jun 2004	141.8 (63.7)	39.2 (25.3)	51.8 (18.8)	85.7 (47.0)
WHO Air Quality Guidelines, 2005		50 (24 hour average) 20 (annual average)	20 (24 hour average)	40 (annual average) 200 (1 hour daily max)	100 (8 hour daily max)

World Health Organization, 2006

#### Air pollution and health during the Beijing Olympics (2007–2010):

For Dr. Junfeng Zhang and his collaborators, the significance of the upcoming Olympics would not be best measured in gold medals or world records, but in biological indicators demonstrating the potential health benefits of improved air quality. As the government aimed to reduce fine particulate matter (PM<sub>2.5</sub>), by approximately 70 percent from pre-Olympic levels, Zhang’s PAPA-supported study will assess whether there are measurable changes in lung and systemic inflammation, blood coagulation, autonomic dysfunction, and oxidative stress in healthy local residents. Moreover, the study will assess whether these biomarkers return to pre-Olympic levels after air pollution controls are relaxed. Exposure to PM<sub>2.5</sub>, ultrafine particles, and key PM constituents will be measured.

#### Health gains from reducing sulfur content in fuel:

Dr. Chit-Ming Wong’s PAPA-funded study, which began in 2006, is assessing the impact of the 1990 Hong Kong restriction of sulfur content in fuel on life expectancy. Earlier studies observed decreased respiratory symptoms in children, decreased mortality from cardiovascular and respiratory disease in adults, and increased life-expectancy as near-term consequences of reductions in SO<sub>2</sub> due to the changes in fuel quality (Peters J et al., 1996; Hedley A, et al., 2002). The current study will evaluate

whether any long-term health benefits are due to reduced SO<sub>2</sub> exposure, or to associated changes in the particle composition of fuels. The study also aims to reconcile evidence on short- and long-term effects of air pollution exposure on mortality and life expectancy.

#### STRENGTHENING THE NETWORK OF ASIAN ENVIRONMENTAL HEALTH SCIENTISTS

PAPA emphasizes applied capacity building through research. For our studies in China, capacity-building work has included:

- Coordinating studies to foster collaboration in study design, study implementation, and consistency of results;
- Building strong links with local health agencies, regulatory officials, and other stakeholders to ensure relevance to local policy decisions and credibility of results; and,
- Funding investigators to present their work at international scientific meetings and regional policy forums.

Due to the high caliber of training and research in Chinese centers of environmental health re-

## // A challenge to addressing the substantial air pollution problems in China is providing quality, credible, and local science to help policymakers decide on the best approaches with the most benefits to public health.”

search, several of our Chinese collaborators have provided technical assistance and training to PAPA-funded investigators in India, Indonesia, Vietnam, and Malaysia.

### CONCLUSION

A challenge to addressing the substantial air pollution problems in China is providing quality, credible, and local science to help policymakers decide on the best approaches with the most benefits to public health. The PAPA Program, by marshaling all of the region’s literature; conducting new, high quality studies with intensive capacity building; and communicating the resulting science in diverse stakeholder forums, is advancing the state of knowledge in China, building a stronger bridge between Chinese scientists and international expertise, and providing the foundation for better air quality decisions.

### ACKNOWLEDGEMENTS

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# FEATURE BOX

## Coal City: China Environmental Health Project Work in Huainan

By Wei-Ping Pan and Ma Tianjie

**H**uainan city, an industrial town in Anhui Province, is often referred to as the “coal-powered Three Gorges” because of its status as the energy base of eastern China. Coal—which provides 70 percent of China’s energy—releases many pollutants into the air including sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), and mercury, resulting in a profound impact on human health and the environment. There are between 400,000 and 750,000 premature deaths attributed to air pollution every year in China. Huainan’s three (soon to be four) coal-fired power plants generate considerable amounts of energy and pollution. Huainan produced 11 million tons of coal in 2004 and is projected to reach 30 million tons by 2030. Due to its crucial place in China’s energy and environmental landscape, Huainan was selected as the location for the coal monitoring activities of the China Environmental Health Project (CEHP)—a U.S. Agency for International Development (USAID)-supported joint project between Western Kentucky University (WKU) and the Anhui University of Science and Technology (AUST). The China Environment Forum works together with WKU and AUST on information dissemination and outreach activities.

### OBJECTIVES OF CEHP COAL PROJECT

The main purpose of CEHP in Huainan is to build the capacity for coal monitoring in the city and to closely examine the effects of heavy coal use and poor air quality on health. Components of this initiative include improving the monitoring system of SO<sub>2</sub>, NO<sub>2</sub>, and PM<sub>10</sub> (particulate matter with diameters measuring less than 10 micrometers); training and educating Chinese researchers and students in the latest techniques; and reduc-

ing coal-related health problems. Because Chinese standards have not been established for some of the pollutants (such as mercury), CEHP work in Huainan employs U.S. Environmental Protection Agency (EPA) standards and sampling equipment to ensure the quality of measurement and analysis.

### CEHP FINDINGS AND ACCOMPLISHMENTS

CEHP teams collected air quality samples from three communities near the three functioning coal-fired power plants in Huainan. They revealed an alarming fact that in the absence of a flue gas desulfurization (FGD) scrubber, 90 percent of the mercury in coal would be released into the air. These findings are significant, considering that Huainan’s coal contains two to three times more mercury than the coal found in other parts of China and the United States. Emissions containing PM<sub>10</sub> are at a dangerously high level in Huainan due to the unusually high fly ash content in Anhui’s coal. Particulate matter in general not only affects air quality visibly—as is seen in the black snow that falls in Huainan—but also causes asthma, lung cancer, and cardiovascular diseases. Even in rain, the levels of particulate matter in Huainan’s air never fall below the U.S. standards for safety. Overall, SO<sub>2</sub> emissions have been decreasing since scrubbers—now mandatory for all power plants in the country—were installed at all three power plants; however, with the addition of a new power plant and the growth of other industries, SO<sub>2</sub> and other emissions will undoubtedly increase in the city.

AUST and WKU researchers gathered information on the effects of heavy pollution on ap-





Western Kentucky University Professor Wei-Ping Pan and two professors from AUST medical school giving lectures on the effects of air pollution on health to elementary school children and faculty in a mining area near Huainan City, Anhui. Photo Credit: AUST

proximately 3,000 elementary and middle school children (ages 11 to 15) and in residential areas in Huainan, comparing it to data gathered in Taiyuan, one of China's 10 most polluted cities. While pollution-induced health problems are increasingly serious in Huainan, the results fared better than Taiyuan in terms of disease burden, which included chronic bronchitis, asthma, constant colds, and other respiratory illnesses.

In September 2008, AUST and WKU held a conference in Huainan to discuss the challenges and successes in compliance and enforcement programs in China; the air pollution monitoring system in Huainan City; as well as the experiences in enforcing U.S. emissions monitoring, reporting, verification, and programs (the latter topic was presented by Jeremy Schreifels (EPA). Also presented were results of studies from the CEHP/USAID air program for the past two years:

- Emissions from three Huainan coal-fired power plants;

- Mercury distribution in the particulate matter emitted from Huainan city;
- The lifecycle of trace metal from coal-fired power plants; and,
- The relationship between particulate matter and meteorological factors.

The impact of climate change on the United States (Jerry Shang, former Department of Energy) and carbon dioxide (CO<sub>2</sub>) capture technologies (Yan Cao, Western Kentucky University) were also topics addressed during the workshop.

#### FUTURE WORK OF CEHP'S COAL PROJECT

Climate change is a growing concern internationally and a growing challenge for China, now regarded as the world's top greenhouse gas emitter. A primary emission of coal use, CO<sub>2</sub>, is

believed to contribute 63 percent of global climate change. Thus, CO<sub>2</sub> capture remains an important area of CEHP research. In 2009, AUST will continue to enhance their partnership with WKU to target these issues with enhanced scientific processes, adding new sophisticated equipment—such as carbon gas-phase monitoring systems—and expanding their monitoring to two new power plants in Huainan. Future work will also be informed by the emerging goals of the recently established Asia-Pacific Partnership on Clean Development and Climate (APP-CDC). As the data accumulates, the team will then collect it in a comprehensive database and disseminate it, with analysis, to decision-makers.

#### **Carbon to Crops Initiative**

Another application of the data is to use captured carbon as a fertilizer in order to store the carbon long-term. CO<sub>2</sub> produced from combustion sources, such as fossil-fuel fired power plants, can be captured from the flue gas. When combined with aqueous ammonia, the captured CO<sub>2</sub> forms ammonium bicarbonate—an economically and environmentally acceptable nitrogen fertilizer. Since ammonium bicarbonate is water soluble, this fertilizer acts as a “CO<sub>2</sub> carrier” to “transport” CO<sub>2</sub> from the atmosphere to crops. About 10 percent is directly absorbed by growing plants. The majority (76 percent) of the remaining carbon percolates into the soil as water-soluble bicarbonates—eventually sinking into aquifers—forming environmentally safe carbonate salts of calcium and magnesium. Generally speaking, alkaline soil better captures and stores carbon.

#### **POLICY IMPLICATIONS OF COAL CITY**

Heavy reliance on coal for energy poses serious challenges for Chinese policymakers. China has stringent regulations for new power plants, but some of the older plants are heavy polluters and shutting down or retrofitting these inefficient plants is costly. Comprehensive monitoring of emissions from old plants and convincing analysis of the deleterious health impacts they are causing can help policymakers better comprehend the total costs of coal emissions. In addition to preventing dirty coal emissions, China needs to stress better energy efficiency, especially in buildings, as it is a cost-effective way to reduce demand for coal-powered energy. Speaking at a May 2008 China Environment Forum meeting, Derek Vollmer of the National Academies noted that because so many cities are developing rapidly, it is also imperative that Chinese cities “build smart instead of build out.” Pollution control will not only save lives but also impact the local economy by reducing the days of work lost and the volume of crops damaged from acid rain, which is especially significant given that much of China’s scarce cropland is located at the peripheries of heavily polluted cities.

*For more information on the CEHP coal project see <http://www.wku.edu/cehp/> or Wei-Ping Pan at Western Kentucky University: [wei-ping.pan@wku.edu](mailto:wei-ping.pan@wku.edu).*

*Ma Tianjie was a summer 2008 research intern at the China Environment Forum. Currently he is in his second year at American University pursuing a Masters at the School of International Service. He can be reached at [tm2198a@american.edu](mailto:tm2198a@american.edu).*

# COMMENTARY

## Neither Black Nor White: Mangrove Conservation With Chinese Characteristics

By Liu Yi (Translated by Jing Chen and Ma Tianjie)

*Fenglinwan, a bay near Xiamen City, Fujian Province, used to be home to the largest area of mangroves in the region. However, beginning in the 1960s, a large campaign to reclaim land from the sea almost erased all the mangroves. Following the reclamation in the bay, just a few mangroves remained in the village of Dongan. In the late 1980s, a farmer in neighboring Jimei village noticed that there were many crabs in the areas where mangroves still grew, and he correctly surmised that there was a healthy relationship between the mangroves and the crabs. At that time, crab was a local delicacy with market prices ranging from 15 to 20 Yuan per kilogram. The villager decided to grow mangroves in another part of Fenglinwan and between 1989 and 1996 he successfully planted 50 mu (1 mu = .1647 acres) of mangroves, with seedlings collected from the original mangroves that remained in Dongan Village. With his gradually improving planting skills, the area of mangroves grew quickly, together with his income. As mangroves became his main source of income, he started to patrol the mangroves regularly to prevent others from damaging them. When other villagers saw the profitability of the mangroves, they joined him in cultivating and protecting this unique coastal ecosystem. Today there are about twenty families from Jimei Village who are in the mangrove-crab business, with the total mangrove area reaching nearly 120 mu. A 1992 National Forestry Bureau policy that granted families exclusive user rights of the mangroves, giving them full access to the profits from crabs and other aquatic products.*

### SEEKING SOLUTIONS FOR DISAPPEARING MANGROVES

Southwest China could be dubbed the mangrove hotspot of northeast Asia, with about 22,300 hectares of mangroves along the coasts of Hainan, Guangdong, Guangxi, Fujian, Zhejiang, Hong Kong, and Macao. China's mangroves are home to 2,305 identified species of animals and plants, including 43 percent of total mangrove species in the world. One-third of China's mangrove species are on the International Union for Conservation of Nature's red list and mangrove areas have shrunk by 55 percent over the last 50 years. Three major historical events have led to the destruction of the mangroves in China: (1) land reclamation projects in the 1960s; (2) reclamation of tidal flats and deforestation for aquaculture in the 1970s and 80s; and (3) urbanization boom from the 1990s to the present.

The Chinese government and a handful of local nongovernmental groups are beginning to take action to protect and expand mangrove habitats. Mangroves, which are trees and scrubs that thrive in salty waters, protect shorelines from wind and sea surges, purify water and serve as vital habitat for birds and seafood.

The China Mangrove Conservation Network (CMCN)—a former student environmental group that has become a professional conservation organization—believes success of any mangrove protection effort hinges on whether it addresses the core needs of all stakeholders depending on this unique coastal ecosystem. For seven years CMCN has been conducting campaigns that have been promoting research, encouraging mangrove rehabilitation and providing public education, community development and training to restore and sustainably use mangroves. CMCN runs 20 ongoing projects on four key topics: (1) sustainable development



Volunteers helping to plant seedlings as part of the mangroves restoration project in Jimei Xiamen, Fujian Province in 2008. It is hard work to plant the mangroves in the mud, and sometimes you need to PLANT yourself first so you can plant the seedlings. Photo Credit: Liu Yi

## BOX 1. History of China Mangrove Conservation Network

China Mangrove Conservation Network (CMCN) was originally a mangrove program under Green Wild, a student organization established in 2000 at Xiamen University. In 2001, Green Wild established a mangrove team to protect mangroves in Xiamen and nearby areas. In 2003, this team was renamed the Mangrove Program, and expanded the protection area to all of Fujian Province. In 2005, the program reoriented itself and adopted the name China Mangrove Conservation Network, which described its new function as a cooperative mechanism linking mangrove protection forces within the country.

CMCN has nearly 40 cooperative nongovernmental entities (including NGOs, communities,

schools, nature reserves, and research institutions); 3,000 volunteers; and 150,000 network members. During the last 7 years, CMCN and its cooperative organizations have hosted thousands of activities, planted 200,000 mangrove seedlings, launched nearly 300 sustainable development education sessions, established 20 demonstration education schools that promote sustainable development of mangroves, and printed a series of educational materials.

CMCN has received wide recognition for its work and won two Ford Conservation & Environment Grants in 2004 and 2006, as well as an award from the Whitley Fund for Nature from Britain in 2008.

education, (2) capacity building for communities, (3) mangrove rehabilitation research, and (4) ecological recovery. The various programs have involved dozens of nongovernmental groups and replanted more than 200,000 mangroves. (See Box 1).

## **EXPANDING THE ROLE OF PUBLIC PARTICIPATION IN RESEARCH AND CONSERVATION**

Scientific research is an effective tool for finding the root causes of environmental problems and their solutions. Research can help communities restore mangroves by increasing the survival rate of planted trees, improving biodiversity, and managing mangroves sustainably. Central in the research is to create an understanding of how people and the mangroves can become a balanced ecological community. Such information can greatly enhance the conservation work of nongovernmental organizations (NGOs) like CMCN.

CMCN has taken advantage of its connection with universities and research institutions to become a professional NGO that carries out effective campaigns and possesses a strong research capacity. A major challenge to this kind of work within NGOs is the public perception (including many of our volunteers) that research is a job for experts. In a role that is perhaps unique among Chinese NGOs, CMCN promotes the concept of “scientific research for all” by designing research projects in which the general public can participate, enabling them to fulfill their own scientific interests in the process.

Over the past seven years, CMCN research and project activities have reached almost all the regions in mainland China where mangroves grow. We have studied the ecology of mangroves including the flora and fauna in mangrove ecosystems, the pests, the water quality, and the soil. We also study the techniques of mangrove planting and nursery. Some of our long-term research projects include: the biodiversity and seasonal change of mollusks in 13 typical mangrove forests in China, the observation of bird communities in mangroves, and the monitoring of mangrove rehabilitation efforts. From May 2003 to April 2004, CMCN organized hundreds of volunteers to assist in a yearlong observation of rehabilitation activities on the Dayu Island of Xiamen. The results provided useful information to the efforts of mangrove recovery, the selection of different types

of mangroves, and promising techniques for transplanting and seedling care for mangroves.

The results of the Dayu Island study revealed that the survival rate of transplanted mature mangroves is low (20 percent). Transplanting also costs more than ten times that of planting young seedlings. This study directly confronts the practice of many urban development projects in China that try to transplant mature mangroves. The study did caution, however, that while young seedlings have relatively higher survival rates, their death rates increase significantly in the winter if not properly maintained. Besides the insights this study provided to urban planners, this project also demonstrated that the general public can participate in meaningful scientific research work.

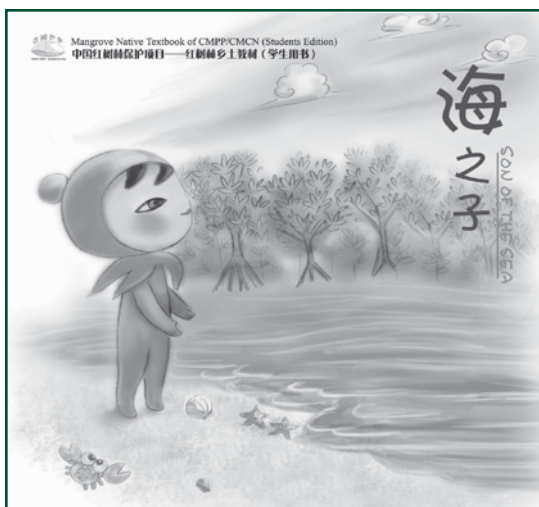
## **EFFECTIVE EDUCATION PROJECTS THAT EMPHASIZE ACTUAL NEEDS**

Public awareness of the vital ecological function played by mangroves and the need for conservation is still very low in China. Sustainable development education is a direct and effective way to raise the awareness of stakeholders who could be involved in the protection of mangroves.

### **Meeting Actual Needs**

CMCN’s educational projects always follow the principle of meeting the actual needs of the various stakeholders. For example, past experiences show that the environmental education models adopted in urban areas are not suitable for many rural communities, especially remote mountainous regions, such as Baise in Guangxi Province where there is not even access to electricity. For such groups there is little point in education about ozone depletion or plastic bag pollution when they are completely disconnected from the consumer market.

In 2004, when CMCN was doing education work on mangrove conservation in Hainan Province, the local elementary schools informed us that they were willing to compile educational materials for their students, but they lacked the expertise and resources. The school needed age-appropriate materials, for over CMCN’s longtime environmental education experience we have learned that people in different regions and age groups have very different needs in terms of the type and content of environmental education. For example, children between the ages 6 and 9 do not like the conventional textbook approach, but prefer fairytale style textbooks and participatory experiences.



Cover of the Son of the Sea textbook that CMCN produced to promote awareness of mangrove conservation in elementary schools. Photo Credit: CMCN

Therefore, CMCN produced a mangrove conservation textbook especially designed for young children called “Son of the Sea.” (See Figure 1). The 12 chapters in this fairytale book each cover a separate theme and are filled with colorful illustrations, games, experiments and questions that facilitate learning through “playing.” At no cost we have produced and provided the schools 5,000 copies of the textbook and 200 copies of the teacher’s manual. CMCN also has trained teachers and volunteers to guarantee the frequency and quality of the weekly course.

### Sustaining Effect

Conventional environmental education is often just outreach in public places using educational boards and leaflets, or ad hoc lectures and teach-ins that have no sustainable effect. Such approaches usually only raise people’s curiosity instead of spreading a green message they can actively sustain.

To make environmental education more sustainable and effective, CMCN has tried many approaches including: establishing mangrove education centers and foundations, initiating online educational platforms, training volunteer eco-tour guides, and producing educational textbooks.

Drawing on five years of experimentation with education work, in 2006 CMCN repackaged its various environmental educational initiatives under a broader initiative—the Sustainable Mangrove Developmental Education Project (SMDEP). SMDEP not only includes environmental education, but also covers relevant social and economic issues. One of the main

features is empowering participating stakeholders to spread the green message during activities.

In terms of environmental education, SMDEP targets all stakeholders. Besides conducting year-long activities in 20 trial schools and 5 demonstration schools, which included training 100 teachers and volunteers, CNCM designed different education approaches for different target groups so that the “sustaining effect” principle will be followed. For example, in elementary schools time slots are generally divided into “class time,” “between-class time,” and “after-class time.” CMCN’s environmental education solution fully covers the three time slots. In class, CMCN trained teachers and volunteers to teach the environmental textbook once a week at trial schools. Between class time slots, CMCN promotes environmental activities such as plant adoption, environmental poster design, environmental broadcasting and photography through small grants and education centers. After class, CMCN helps the students conduct research-based studies that are relevant to conservation. The yearlong project has demonstrated that this approach achieves the goal of being sustainable and effective.

### Lasting Results

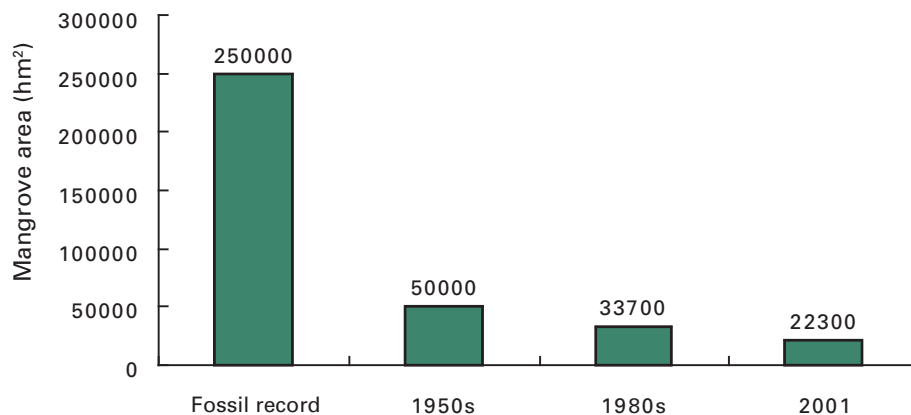
Of one thousand students that used the “Son of the Sea” textbook, the majority of students, teachers and schools gave very positive feedback on the trial. At the end of 2006, CMCN’s Sustainable Mangrove Developmental Education Project was

Figure 1: Species Biodiversity of Mangroves in China

CATEGORY	SPECIES NUMBER
Higher Plants	70
Fish	249
Algae	494
Birds	370
Benthic (Shoreline) Fauna	650
Insects	440
Amphibians and Reptiles	18
Mammals	14
<b>Total</b>	<b>2305</b>

Source: Wang & Wang (2007). *The Mangroves of China*. Science Press of China.

Figure 1: Changes In the Area of Mangroves in China



granted the “Asia Good Practice ESD Practice Project Award” by the United Nations Ten Year Sustainable Education Program. The yearlong environmental education trials in the 20+ schools generated a large amount of writings and drawings from participating students, which generated news media reports and attention from government departments, research institutes and other NGOs.

### COMMUNITY DEVELOPMENT: A “WIN-WIN-WIN” SOLUTION

Community development is the most direct way to solve the mangrove issue and achieve a winning solution for the economy, society and environment. Almost all environmental problems are combinations of larger problems in the community, which usually can be summarized as economic development at the expense of the environment. In order to solve these problems, we must start with community development to promote sustainable, alternative development models.

#### Living by the Mountain: Intensive Aquaculture versus Mangroves

One Chinese proverb states that “if you live by the mountain, you rely on the mountain to live.” Before the 1960s, Chinese fishers living around the mangroves survived on wild catches, which put relatively limited pressures on the mangroves. However, as the human population grew and development became more resource intensive, exploitation of mangroves also intensified in China. Many unsustainable development models, such as

clear-cutting mangroves for aquaculture, started to appear. Intensive aquaculture not only destroys the foundation of the original wetland and the mangroves, the highly-concentrated wastewater it generates is often discharged directly into the mangrove areas nearby, seriously polluting the water.

As the soil that mangroves live on is often acidic, and therefore unsuitable for aquaculture, many aquaculture farms witness continuously declining output every year. In many places in China and Southeast Asia, aquaculture farms are abandoned after just a few years. Farmers would then fell more mangroves to start new aquaculture farms. Between growing seasons, the fishermen often dig out the soil of the wetland and “sterilize” it by basking it in the sun and mixing it with lime and pesticides. This practice aims to protect aquaculture from diseases and pests and extend the life of the fish farm by raising the pH of the water, but such “cleaning” processes severely degrade the soil and affect surrounding ecosystems.

Intensive aquaculture in mangroves itself is highly risky: In years without natural disasters, the farmers might gain tens of thousands of dollars, but when faced with disease outbreaks or hurricanes, their losses can also reach tens of thousands. Farmers thus aim to maximize profits quickly and serve their immediate interests, for “If I cannot feed myself, how do I care for the environment?” Therefore, simple environmental education and outreach will not work in fishing communities. The real solution in such a situation is to give farmers what they need—more money—while at the same time protecting the mangroves for their own interests.



Land reclamation that began in the 1960s destroyed most of the mangroves in Fenglin Bay near Xiamen City (Fujian Province). Beginning in the late 1980s, some families from Jimei Village along the bay began restoring the mangroves to help their cultivation of crabs. This grassroots restoration is a model for community development and mangrove protection. Photo Credit: Liu Yi

### Searching for Solutions

CMCN has realized the importance of community development since 2003. Over the past few years CMCN staff and volunteers have started a nationwide search for cases of sustainable community development, evaluated them, and promoted the most promising ones. We have found several such cases including the Jimei Fenglinwan Mangrove case that opened this article and the Guangxi Duck Egg case. (See Box 2). Currently, CMCN is trying to promote the Guangxi Duck Egg model in other places, such as in the Jiulong River basin in Longhai, Fujian Province where CMCN has been operating a “Beautiful Backyard Action.” In the 1980s, there used to be many mangroves in the Nan Branch River of Jiulongjiang River in Longhai. But because of high-speed boats and economic development in the basin, almost all of the mangroves disappeared. So CMCN initiated the “Beautiful Backyard Action, which consists of three activities over a five-year period to promote the local community development. The first step has been to undertake efforts to reforest the mangroves; next CMCN has worked to increase the public awareness on mangroves conservation and public participation. The third and final stage will be to help the local

villagers along the Nan Branch River to develop with the sea-duck egg project or other sustainable community development projects. Our model of community development uses the economic interests of local fishermen as a starting point.

### ECOLOGICAL RECOVERY: AFFORESTATION, MONITORING AND MAINTENANCE

The problems facing mangroves are not simply low public awareness. A bigger problem is that there are increasingly fewer suitable locations for mangroves to flourish. If relying on natural recovery, mangroves in China could not recover to their 1950 level in 200 years. Therefore, afforestation efforts based on science are imperative.

The Chinese government has recognized the mangrove crisis and has started taking action. The State Forestry Administration (SFA) promulgated the National Wetland Protection Action Plan and the National Wetland Protection Blueprint in 2000 and 2004, respectively. Besides conserving the existing 22,300 hectares of mangroves, the SFA also plans to increase them by 65,900 hectares through rehabilitation before 2030. Since the end of the

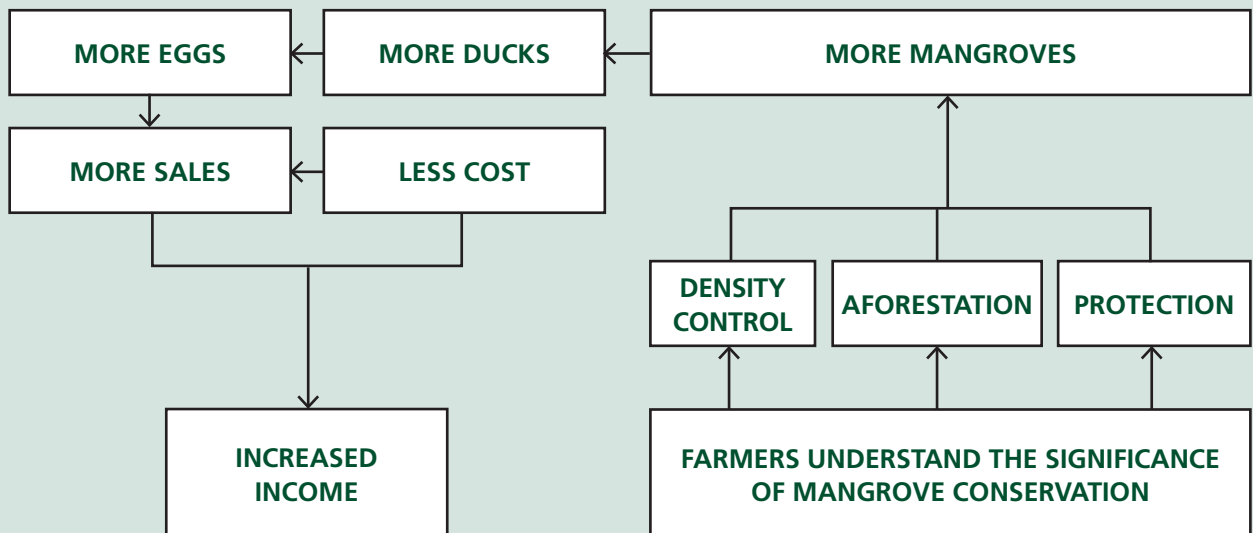


## BOX 2. Duck Egg Model

### GUANGXI DUCK EGG CASE: "RED-HEART EGG" PROMPTS MANGROVE CONSERVATION

Red-heart salty egg is a famous local delicacy of Fangchenggang in Guangxi Province and mangroves play a crucial role in the production of these eggs. The local fishermen put ducks in the mangrove area. As the mangrove ecosystem provides the ducks with a rich supply of small fish, shrimps and seashells, the fishermen do not even need to buy feed, which significantly reduces costs. In addition, the mangroves have a water cleansing function, which makes the ducks and their eggs organic food that are con-

sidered to be tasty and having a high nutritional content. Even though the eggs are three times more expensive than regular eggs, the sales are guaranteed. In Fangchenggang, local fishermen understand that the mangroves have their own carrying capacity, which should not be overexploited. Only a suitable number of ducks can ensure the quality of their eggs. In order to profit more from the eggs, the fishermen both protect the mangroves and have made efforts to expand the size of local mangroves. The flow chart below captures the positive interactions that occur when farmers begin their work with the understanding that healthy mangroves will help their duck egg sales.



1990s, some large mangrove reserves, such as the Zhanjiang National Mangrove Nature Reserve and Hainan Dongzhaigang National Mangrove Nature Reserve, have taken on large-scale rehabilitation actions. Some municipal governments also have prioritized the protection of mangroves under their jurisdiction. For example, in 2007, the Xiamen government set aside 100 million Yuan to recover 2,000 *mu* of mangroves.

For the past 7 years, CMCN has been promoting public efforts of mangrove rehabilitation through research, compiling scientific literature reviews and expert interviews. The resources were then freely provided to our partner institutions with some funding and training. We also assisted different groups in obtaining seedlings and organizing volunteers to participate in tree planting. So far, CMCN and its partners have planted 200,000 mangroves in 5 southeastern provinces, with a survival rate higher than 90 percent.

Tree planting is just the first step of rehabilitation: Monitoring and care afterwards is crucial to survival, which is why CMCN has initiated long-term monitoring and care on Dayu Island and Jimei.

## THE FUTURE OF CMCN AND CHINA'S MANGROVES

After decades of exploitation, it is now time that the mangroves be protected and restored. Fortunately, China has established 23 Mangrove Nature Reserves (including 6 national-level reserves), which cover about 75 percent of China's mangroves. Relevant government departments have begun to pay more

attention to the issue, and social groups are starting to exert more influence.

The future work of CMCN will be challenging, but we plan to continue campaigns that raise public awareness of mangrove conservation and conduct projects that both protect and rehabilitate mangrove ecosystems while simultaneously promoting community development. We hope to strengthen our network by constructing an interactive online network of nongovernmental mangrove protection groups. Together with these groups we will conduct more basic research on mangroves that will help inform the development of regulations to promote mangrove conservation and push to establish a national mangrove destruction alert system. CMCN will also be seeking partners to explore the relationship between mangroves and climate change.

*Liu Yi has been the lead campaigner for the China Mangrove Conservation Network for seven years. In May 2008 Liu Yi became the youngest ever recipient of a Whitley Award, which was presented to him by the UK's Whitley Fund for Nature for his work to restore and expand the mangrove forests on the eastern coast of China. He can be reached at: china\_mangrove@126.com.*

*The two translators of this commentary—Jing Chen and Ma Tianjie—were both summer 2008 research interns at the China Environment Forum. Jing Chen is a graduate student at the University of Maryland and can be reached at jichen@gvpt.umd.edu. Ma Tianjie is in his second year at American University pursuing a Masters at the School of International Service. He can be reached at: tm2198a@american.edu.*

# SPOTLIGHT

## The Forest Stewardship Council: Because Forests and People Matter

By Marion Karmann

### CHINA'S FORESTS

China's temperate and tropical forests are some of the most biologically diverse in the world, and in mountainous areas, they regulate water flow to lowland agricultural fields. Widespread deforestation of natural forests in the past caused acute consequences. In 1998, for example, thousands of lives were lost as disastrous floods decimated entire towns and villages. China has drawn consequences: over the past 30 years, China increased its forest coverage from 12 percent of total land area to 18 percent—a phenomenal achievement never matched by any other country—through a concerted plantation program over vast areas of the country and a government ban on commercial logging of natural forests in 17 provinces. However, while intended to conserve forest landscapes, the ban has not only fuelled the sharp increase of illegally and irresponsibly harvested wood and pulp imports from Southeast Asia and Siberia, but also has created hardship for local families whose livelihoods depend on logging.<sup>1</sup> At the same time, the success of China's forest plantation program is the main reason why the global rate of deforestation slowed down in the first five years of this century.<sup>2</sup> China's ambition is to increase forest coverage to 23 percent by 2020. The resulting effect would narrow the gap between domestic timber supply and demand, reduce pressure on fragile ecosystems, and help to absorb more carbon dioxide, the main agent of climate change.<sup>3</sup>

### CHINA'S WOOD INDUSTRY

China's market for industrial timber, pulp, and paper is the second largest in the world—outranked only by the United States—and its position in the global marketplace is likely to become more pronounced in the next decade. Nearly half of all tropical trees harvested worldwide are utilized by the

Chinese goods-producing sector. This is due in part to increasing domestic demand, but also to growing international demand for China's low-cost finished wood products, such as furniture. China may soon overtake the United States as the primary destination for illegal timber exports from some South American countries—particularly as raw material for China's flooring and furniture exports<sup>4</sup> to the North American and European markets.<sup>5</sup>

As for the domestic sphere, over half of China's wood fibers still come from Chinese forests, despite the timber ban. Local communities practice subsistence gathering of wood fuel and fruits and medicinal plants, further straining resources. China is now looking at how it can resume logging in state forests in a sustainable way—maintaining wildlife habitat and controlling flooding and erosion. As the government reviews its forest strategy, the development of responsible management certification and a national forest stewardship standard are key steps in the progress towards responsible forest management in China.

### THE FOREST STEWARDSHIP COUNCIL

The Forest Stewardship Council (FSC) is an international nonprofit membership-based organization aiming to develop such certifications and standards in China. FSC sets international framework standards for responsible forest management and establishes multi-stakeholder working groups (FSC National Initiatives) to develop indicators appropriate for national and regional forest management through consultative processes. FSC accredits independent third-party organizations who can certify forest management and forest product producers, known as the Chain of Custody, according to these FSC standards. Throughout the past 13 years, over 90 million hectares in more than 70 countries have been certified according to FSC standards, while several thousand products are produced using

FSC-certified wood and carrying the FSC trademark. In China, FSC is working on two initiatives: timber certifications and non-timber forest products (NTFPs).

## CERTIFICATION OF TIMBER PRODUCTS

China's FSC National Initiative was launched in March 2006, with the support of China's State Forest Administration, the Chinese Academy of Forestry, the WWF-China and many others. Accredited by FSC in June 2007, it joins the 45 other accredited FSC National Initiatives around the world in their mission to promote responsible forest management. The FSC National Initiative in China is leading the development of a set of Chinese national standards that can be recognized internationally by FSC.

Given China's role in the world's timber markets, the development of an FSC-accredited National Initiative in China presents truly global opportunities for creating incentives for better forest management, both in China and in some of the world's most threatened forests, while at the same time providing significantly more responsibly produced wood products for the North American and European markets.

While the National Initiative is still elaborating the FSC China national forest management standard, FSC certification in China based on generic standards is growing quickly, particularly in Chain of Custody. In January 2008, over 370 Chinese timber processing companies received FSC Chain of Custody certificates, and the numbers are increasing at an astonishing rate. At the same time, China had seven Forest Management Units covering more than 550,000 hectares certified according to FSC standards. However, in 2005, China's forest coverage was 175,000,000 hectares, which means the FSC certified areas accounted for only 0.3 percent of total forested area—leaving much opportunity for the project to expand. A number of other large forest holdings and community forest projects with a strong focus on NTFPs are also currently working towards certification.

## NON-TIMBER FOREST PRODUCT CERTIFICATION: FOOD AND MEDICINE FROM THE FORESTS

Apart from providing timber, forests also play a vital role in global food security, providing nutri-



The majority of Yunnan's upland population remains poor and heavily dependent on the natural environment for its livelihood. Photo Credit: Forestry Stewardship Council

tion, fodder, fuel, and medicine, as well as a source of paid employment for rural communities. Only by managing these resources sustainably will communities be able to utilize them in the years to come.

Southwest China—characterized by diverse mountainous terrain and climate, a large population of ethnic minorities, rich biodiversity, and increasing pressure on natural resources—is renowned for the wealth of NTFPs including pine seeds, mushrooms, walnuts, and an array of medicinal plants. The majority of the upland population remains poor and heavily dependent on the natural environment for its livelihood, as it has been for hundreds of years. The products from natural and planted forests play an important role in the household economy, especially in remote areas where other business opportunities are lacking. With the enforcement of a strict logging ban in 2000 on all natural forests, and the gradual conversion of land above 25 degrees of slope from grain into tree crops under the Sloping Land Conversion Program, many upland communities lost a significant source of income. Some households have substituted this loss by intensifying the collection of NTFPs from natural and planted forests, overharvesting selected products and thus posing a threat to biodiversity. Yet, most collectors/producers only earn a small income from NTFPs, because they lack basic market knowledge and rely on traders to buy their products.

Despite local prominence, the economic and conservation potential of NTFP production and harvesting has yet to be realized on a larger scale



Forestry Stewardship Council has partnered with WWF-China and the Center for Mountain Ecosystems Studies to pilot projects on NTFP certification with communities in upland Yunnan. Photo Credit: Forestry Stewardship Council

in southwest China. Many Chinese farmers are not aware of the market potential of NTFP or how to cultivate them. For NTFPs which are not easily domesticated, such as Matsutake mushrooms and truffles, management regimes often need to be established to ensure sustainable harvesting. In both cases, marketing tools and knowledge (including branding and certification) are not available to upland communities, and the linkages between NTFPs and conservation often go unnoticed.

A potential solution that could benefit and bridge economic and environmental goals is product certification under organic, fair trade and/or sustainable forest management schemes. NTFPs that can be dried, further processed, and stored—such as nuts, medicinal plants, and mushrooms—may be particularly suitable since distance to markets poses a serious logistical challenge. At present, the relatively wealthier consumers of certified products are only found in China's big eastern cities or abroad.

### NTFP Pilot Project

FSC, together with the Center for Mountain Ecosystems Studies (CMES) and WWF-China, are currently seeking support for a pilot project on NTFP certification with forest-dependent upland communities in Yunnan and Sichuan provinces. The aim of the project is to generate income for poor households while preserving biodiversity and averting environmental degradation and pollu-

tion. Specifically, the project intends to develop a successful and replicable model of marketing NTFP as certified organic food (with established markets) and small-scale responsible forest management through FSC certification. Based on preliminary research findings and initial community consultations, this project will pursue a joint FSC and organic certification, targeting China's East Coast and overseas markets. The project will run 12 months to ensure the establishment of a first certification, leading to further funding from the private and public sectors and ensuring participants are able to market their own goods. After three years, the project is expected to be self-sufficient and expanding. The core of the project is developing capacity among Chinese community members, government agencies, and project staff to certify and market NTFPs. Community members will be given a strong voice in the consultation processes related to the FSC certification.

*FSC's activities in China have been kindly supported by the Wallace Global Fund, the DOEN Foundation, the FSC Global Fund, and WWF. For further information about the FSC, visit their website at [www.fsc.org](http://www.fsc.org). For further information about the CMES/FSC/WWF project "certification of non-timber forest products," contact Mr. Alistair Monument, technical director FSC China at [china@fsc.org](mailto:china@fsc.org). Marion Karmann is on the development team at FSC International Center in Germany. She can be reached at [m.karmann@fsc.org](mailto:m.karmann@fsc.org).*

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