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FEATURE ARTICLE

Seeing Through the Smog: Understanding the Limits of Chinese Air Pollution Reporting

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Although the debate over exact statistics rages, as many as 400,000 premature deaths could be avoided each year if Chinese cities met domestic air quality standards. Over the past decade, the Chinese government has been promoting environmental information disclosure as a new policy tool, both to raise public awareness of pollution problems and to strengthen enforcement of pollution control laws. Two of the most extensive environmental information disclosure initiatives have been public air quality reports and ranking Chinese cities by air quality. Utilizing a comprehensive dataset of weekly (1998-2000) and daily (2000-2007) Air Pollution Index (API) reports, this paper not only examines air quality trends, but also evaluates the limits of the API system to accurately communicate air quality problems. The API system has been weakened both by irregularities in the monitoring and the central government's move in June 2000 to relax national air quality standards. This paper discusses the significant discrepancies that exist between analyzed pollution trends and reported progress in the Ministry of Environmental Protection's State of the Environment reports and Annual City Air Quality Rankings. Misinterpretation and/or manipulation of public air quality reporting in China have hindered the public awareness that it is ostensibly intended to promote. The Olympics held in Beijing in 2008 increased international and domestic awareness and concern for the quality of China's air and also exposed many of the inconsistencies between the API system and actual impacts on human health.

AIR POLLUTION QUANDARIES IN CHINESE CITIES

Although many cities in China have monitored air pollution for decades, this information was not publicly released until the late 1990s. In describing the publishing of weekly air quality reports that began February 28,1998, in Beijing, *The New York Times* reported: "For 20 years, local officials carefully measured this city's air pollution levels and equally carefully hid the results—fearing that the truth might tarnish the capital's image or lead to social unrest" (Rosenthal, 1998). *Nature* magazine (1998) accompanied a description of Beijing's weekly air quality reports with a cartoon depicting two people in a cloud of smog commenting: "At least in Beijing we now have weekly pollution reports." "Yes. If only we could see them." An official in Shanghai hesitant about the release of this information observed, "If we simply release the information to the public, the disadvantages would outweigh the advantages….They may say, the government did a bad job. Why did you give us such bad air?" (U.S. Embassy, 1998).

Despite initial insecurity on the part of officials, since 1998, every day millions of people throughout China read, watch, or hear air pollution reports published in newspapers, broadcast on television, and announced on the radio. An environmental official in Beijing heralded the transparency noting that, "Releasing the numbers is a revolutionary concept for the people and the government. We were worried that people would complain that air pollution is too serious. Instead, the consciousness of people has been raised. And they feel the Government trusts them with the facts" (Rosenthal, 1998).

API TO BLUE SKY: WHAT THE PEOPLE HEAR

China's pollution information includes reports on the atmospheric concentrations of three pollutants: particulate (TSP from 1998-2000, and PM_{10}

from 2000-2007); nitrogen oxide (NOx from 1998-2000 and NO_2 from 2000-2007); and sulfur dioxide (SO_2), which are averaged over 24-hour periods and multiple monitoring stations to produce a single API value for major cities ranging from 1 (clean) to 500 (hazardous). The APIs are calculated based on the average concentration of each pollutant, but only the highest API is reported by China's Ministry of Environmental Protection (MEP). Higher values indicate greater potential impact on human health. An API value of 100 or less indicates attainment of China's National Ambient Air Quality Standards (NAAQS) for residential and commercial areas and satisfactory air quality. However, both China's 1996 and revised 2000 NAAQS are far below World Health Organization (WHO) guidelines and public reporting does not take ozone and fine particulate into account.[1]

In the capital of Beijing, as well as in many other Chinese cities, days that meet the national standard are called "blue sky" days (BOCOG, 2006; *Shanghai Daily 2006;* Chongqing EPB, 2007; *People's Daily*, 2001; *Invest Guangzhou*, 2007). The annual numbers of these attainment days have become the most watched public metric of China's air quality progress (Beijing EPB, 2006; Shanghai EPB, 2006; Wuhan EPB, 2006). Although air quality in Chinese cities was previously ranked based on a compilation of annual average pollution concentrations, the 2006 rankings evaluated cities based on the percentage of days meeting the national air quality standards (SEPA, 2007). These changes in the rankings criteria have placed additional pressure on local officials to meet blue sky targets, as the results are published as part of a "name and shame" approach (OECD, 2007).

In 1994, 20 percent of Chinese cities with a population of over 2 million exceeded the Chinese national standard for nitrogen oxides, and this number would increase to 82 percent in 1998. (He & Chang, 2000). In 2005 and 2006, not a single one of the 559 cities monitored exceeded the national nitrogen oxides standard (SEPA, 2006 & 2007), a reflection of a weakened revised standard rather than reduced pollution.

Publicizing the API and where cities rank in terms of air quality keeps the public informed of air quality and potential health threats. However, misleading data presentation and revised laws have prevented the API system from accurately communicating air quality problems to the public. To better understand the challenges and opportunities that exist for China to strengthen air quality standards and reporting, this article analyzes the trends in 3,249 weekly and 171,101 daily API reports published online by MEP (www.mep.gov.cn) between 1998 and 2007. Beginning in 1998, only a handful of cities reported weekly monitoring data, but by mid-2000 46 cities were publishing API reports. In 2000, MEP began recording daily reports in 42 cities, and expanded the program to 86 cities by 2007. This article concludes with some comparison of the U.S. experience in developing air measurement tools and rankings.

EBB AND FLOW OF PUBLIC POLLUTION INFORMATION

Access and open discussion of pollution information in China has increased over the past decade, but there are times when some agency or individual deems certain information too sensitive. China's groundbreaking Green GDP project met an early demise after provincial officials stood up against efforts to publicize the local health and economic effects of pollution. Journalists, who since the late 1990s had been given fairly free reign to report on pollution issues were constrained significantly in the aftermath of the 2005 benzene spill on the Songhua River, and were instructed to put a positive spin on Beijing's pollution crisis in the months leading up to the 2008 summer Olympics. 2008 saw the passage of freedom of information legislation, under which MEP passed measures to promote access to environmental information, which will potentially give journalists more freedom to report on pollution problems once again (Gang, 2008).

INCONSISTENT RELEASE OF HEALTH EFFECTS

In 1997, the World Bank's seminal study of China's environmental quality—*Clear Water, Blue Skies*—estimated that 178,000 premature deaths could be avoided per year if China met its own national air quality standards (World Bank, 1997). Officials in MEP continued to cite this shocking estimate for years (Johnson, 2005). The long-awaited update, *Cost of Pollution in China: Economic Estimates of Physical Damages,* done by the World Bank in collaboration with MEP is still in its conference edition, but in 2007 the updated estimates of mortality and morbidity in China due to air pollution were removed (World Bank, 2007). According to the United Kingdom's *Financial Times*, the Chinese government deemed the

Figure 1. Primary Pollutants of Concern 1998–2000

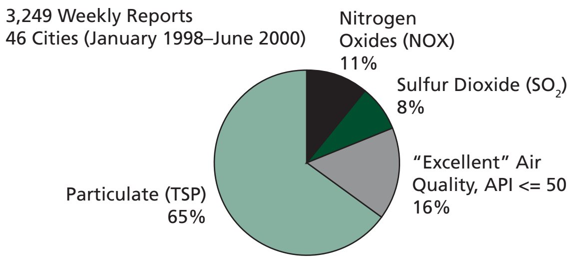
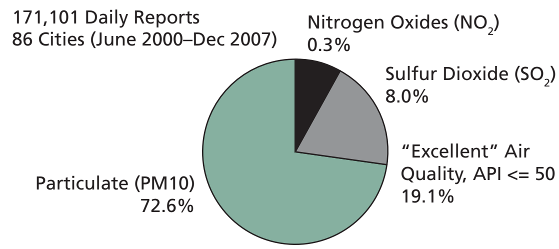


Figure 2. Primary Pollutants of Concern 2000–2007



Source: Author's calculations from MEP online monitoring reports

estimate of 350,000 to 400,000 premature deaths per year due to urban air pollution as too sensitive, which could lead to social unrest (BBC, 2007).

Recent research published in the scientific literature by professors at the Department of Environmental Science at Peking University calculated mortality from ambient air pollution in China at 281,361 for 2004 (Zhang et al., 2007a). The same research group estimated that air pollution in 2004 resulted in 23,733 premature deaths for the city of Beijing alone (Zhang et al., 2007b).

CHINA'S AIR QUALITY STANDARDS

Main Pollutants of Concern

Although China's API is based on measurements of particulate (PM_{10}/TSP), nitrogen oxides (NO_2, NOx), and sulfur dioxide (SO_2), only a single index value and the pollutants with the greatest potential health impact are indicated in public reporting. The pollution monitoring reports between 1998 and 2007 became more widespread and comprehensive after 2000, shifting from weekly to daily and nearly doubling the number of cities. As Figures 1 and 2 illustrate, particulate remains the biggest health threat, and the government's years of targeting sulfur dioxide emissions has succeeded in holding atmospheric concentrations relatively steady. The percentage of excellent air quality reports (API of 50 or less) grew slightly in the latter seven years, but the increase in sample size makes clear conclusions about progress difficult.

With the exception of ozone, China reports the main pollutants for which WHO provides guidelines.[2] The environmental health threats of these main pollutants are discussed below:

- *Particulate (PM_{10}/TSP)*—Particulate matter includes both solids and liquids that can be either emitted directly or formed in the atmosphere when other pollutants react. Particles less than 100 micrometers are called total suspended particulate (TSP); less than 10 micrometers are called coarse particulate (PM_{10}), and less than 2.5 micrometers are called fine particulate ($PM_{2.5}$). Particulate less than 10 micrometers can enter into the lungs and cause serious health damage. However, particulate less than 2.5 micrometers have been found to be a better indicator of the impacts of particulate pollution on human health. As a result, many countries and WHO have switched from standards based on TSP to PM_{10} and then to $PM_{2.5}$, although WHO also maintains a PM_{10} standard. China switched to measuring from TSP to PM_{10} in 2000, and there is currently limited monitoring of $PM_{2.5}$. Particulate matter, especially $PM_{2.5}$, has been linked to illnesses and premature death from heart and lung disease with both short-term exposures over single days and long-term exposure over years (WHO, 2005).

- *Nitrogen Oxides (NO_2/NOx):* Nitrogen dioxide is a toxic gas and has often been used as an indicator of combustion-related pollutants including road traffic. In 2000, China switched from measuring nitrogen oxides to measuring nitrogen dioxide consistent with changes in the United

States and many countries around the world. Nitrogen dioxide is a key precursor (in addition to volatile organic compounds (VOCs)) of surface ozone and of nitrate aerosols, which form a significant fraction of the $PM_{2.5}$ mass (U.S. EPA, 2003; WHO, 2005).

- *Sulfur Dioxide (SO_2)*: A colorless and reactive gas, SO_2 is produced from the combustion of fuels that contain sulfur including coal and oil. The highest levels of SO_2 are usually located near industrial areas, with major emissions coming from power plants and industrial boilers (U.S. EPA, 2003). The Chinese government has undertaken major campaigns (e.g., mandating desulfurization equipment on new plants) to slow SO_2 emissions, but the continued rapid growth of coal-fired power plants appears to have kept atmospheric concentrations in major cities relatively steady.

- *Ozone*: Composed of three atoms of Oxygen (O_3), ozone in the upper atmosphere helps protect humans from ultraviolet rays; ground level ozone causes significant health effects. Some researchers have calculated that the health effects of ozone are of comparable magnitude as particulate (ECON Centre, 2002). Ozone is formed when nitrogen oxides emitted by cars, power plants, industrial boilers, refineries, chemical plants and other sources react with VOCs emitted by these and other sources when exposed to sunlight. The health effects of ozone include inflammation and damage to the lining of the lungs, increased susceptibility to respiratory infections, irritation to the respiratory system, and difficulty breathing. Although China has an hourly ozone standard, ozone is not generally included in API reporting. Certain cities, including Beijing from 1998-2000 reported an ozone API, but reporting has not been consistent, and Beijing has now officially stopped measuring ozone, although it has announced plans to measure it again in the future (UNEP, 2007).

HEALTH IMPACTS OF AIR POLLUTION IN CHINA

The studies by Zhang and the World Bank calculate air quality based on annual average concentrations of total suspended particulate (TSP) and coarse particulate (PM_{10}). The statistic that only 1 percent of China's 560 million city dwellers breathe air considered safe by the European Union has been often repeated (World Bank, 2007; Kahn & Yardley, 2007). However, an assessment of annual average coarse particulate (PM_{10}) concentrations and WHO global guidelines presents an even bleaker picture. Not a single one of the 108 cities included in MEP's 2006 city rankings achieved the WHO guidelines for annual average coarse particulate concentrations (SEPA, 2006; WHO, 2005).

The World Bank and Zhang studies used annual average particulate concentrations as an indicator of the overall impacts of air pollution. The premature death numbers (281,361 nationwide and 23,733 for Beijing) due to air pollution in 2004 were based on the use of a single indicator pollutant to calculate the health effects of pollution to avoid overestimation of the impacts (Zhang et al., 2007a; Kunzli et al., 2000), and therefore did not take into account the complex combinations of pollutants.

The health impacts for 2004 in China and 2002 in Beijing have been previously calculated and are summarized in Box 1 (Zhang et al., 2007a, b). These two studies by the same research group actually used different threshold concentrations to calculate the health impacts of air pollution. If the zero-effect threshold used in the study for Beijing was applied to the China-wide study (based on WHO findings that health risks are present at any level of exposure) then the estimated health impacts would be much higher (WHO, 2005).

For example, the Beijing study also estimated the mortality for Beijing in 2004, which they found to be 23,733 (Zhang et al., 2007b). However, the China-wide study using the same population and annual average PM_{10} concentration estimated the mortality at 17,886 (Zhang et al., 2007a), because they assumed that health effects of PM_{10} pollution did not begin until annual average PM_{10} concentrations exceeded 40 micrograms per cubic meter ($40\mu g/m^3$). The China-wide study calculates that the economic cost of air pollution using $40\mu g/m^3$ is \$29.178 billion in 2004 (in 2004 USD), while using the zero-effect threshold it is \$40.740 billion USD for 2004—40 percent higher than the impacts calculated using the higher threshold (Zhang et al., 2007b). This means that if the same zero-threshold analysis had been applied for all of China that there would have been an estimated 400,000 premature deaths[3] due to air pollution in 2004, which is on the high-end of the estimate included in the censored 2007 World Bank report (BBC, 2007). In light of these studies, it merits investigation whether China's API system adequately informs the public of these serious health risks.

BOX 1.

ESTIMATED NUMBER OF CASES ATTRIBUTABLE TO PARTICULATE AIR POLLUTION IN 111 CHINESE CITIES.

Source: Zhang et al., 2007b. (Parentheses indicate 95 percent confidence interval)

- **Mortality** 281,361 (190,279 – 359,575)
- **Chronic Bronchitis** (681,081 (240,454 – 980,158)
- **Respiratory Hospital Admission** 69,037 (47,564-89,191)
- **Cardiovascular Hospital Admission** 99,931 (44,344-151,900)
- **Outpatient Visits**—internal medicine 3,037,669 (2,413,209-3,661,982)
- **Outpatient Visits**—pediatrics 673,008 (461,887-874,720)
- **Acute Bronchitis** 2,100,733 (912,762-2,893,975)
- **Asthma Attack**s 2,655,022 (1,573,426-3,516,391)

ESTIMATED NUMBER OF CASES ATTRIBUTABLE TO PARTICULATE AIR POLLUTION IN URBAN DISTRICTS OF BEIJING IN 2002.

Source: Zhang et al., 2007a. (Parentheses indicate 95 percent confidence interval)

- **Mortality for individuals 30 years and older** 25,146 (18,325-30,479)
- **Chronic Bronchitis** 62,342 (32,547-80,725)
- **Respiratory Hospital Admission** 9,070 (6,444-11,499)
- **Cardiovascular Hospital Admission** 10,064 (4,684-15,026)
- **Outpatient Visit to Internal Medicine** 361,579 (208,848-509,993)
- **Outpatient to Pediatrics** 120,100 (46,033-190,546)
- **Acute Bronchitis** 162,929 (85,632-211,566)
- **Asthma Attacks** 221,522 (153,278-272,345)

Note: The 2002 health effects study was based on Beijing's urban population of 9.5 million and annual average PM_{10} concentration of 165µg/m^3.

GAPS IN CHINA'S AIR QUALITY STANDARDS AND MISLEADING STATISTICS

The daily air quality reports that are open to the public are misleading for a number of reasons, most striking is the fact air emissions in compliance with the China's air emission standards may not indicate safe levels of air pollution. Moreover, China's API reporting system does not clearly communicate health impacts. While considerable data is collected and posted online, and monitoring stations are sometimes moved to less polluted areas, skewing long-term data.

National ambient air quality standards were first promulgated in 1996, and then revised in 2000. Notably, the 1996 Chinese national ambient air quality standards are considerably less stringent than the 2005 WHO standards.[4] The 2000 revisions to the 1996 Chinese standards for nitrogen oxides and ozone further reduced the stringency of these standards. (See Table 1).

Particulate Concentrations

In 2005, air quality reports revealed that the annual average PM_{10} concentration in many Chinese cities was far above WHO, U.S., and even Chinese

Table 1: Chinese Air Quality Standards and WHO Guidelines

		CHINA 1996	CHINA (2000)	WHO (2005)
Particulate (TSP)	Daily	300	--------	--------
	Annual	200	--------	--------
Fine Particulate (PM10)	Daily	150	150	50
	Annual	100	100	20
Nitrogen Oxices (NOx)	Daily	100	--------	--------
	Annual	50	--------	--------
Nitrogen Dioxide (NO_2)	Daily	80	120	--------
	Annual	40	80	40
Sulfur Dioxide (SO_2)	Daily	150	150	20
	Annual	60	60	--------
Ozone		160 (1 hour mean)	200 (1 hour mean)	100 (8 hour mean)

Pollutant concentrations are indicated in micrograms per cubic meter of air (µg/m^3).
Note: Shaded areas indicate where revised 2000 Chinese standards are higher than the 1996 Chinese standards.

standards: Harbin (104µg/m^3), Nanjing (110 µg/m^3); Wuhan (111µg/m^3); Chengdu (120µg/m^3); Shijiazhuang (133µg/m^3); Datong (154 µg/m^3); and Lanzhou (157 µg/m^3). Guilin, which had the best air quality of ranked cities, with an annual average PM_{10} concentration of 29 micrograms per cubic meter (29µg/m^3) in 2005, was still 45 percent above the WHO guideline of 20µg/m^3. Kunming publicly reported that its air quality met the Chinese national standard on 353 out of 356 days, but its annual average PM_{10} concentration of 83µg/m^3 was over four times the WHO guideline. Only 5 percent of Chinese cities included in MEP's ranking were below the U.S. standard of 50µg/m^3 for PM_{10}, although 53 percent of the cities met the Chinese standard of 100µg/m^3—a level five times higher than WHO guidelines.

Although Beijing was not included in MEP's 2006 rankings, the annual average PM_{10} concentration in Beijing for 2006 was 161µg/m^3—no better than 2002, a year for which over 25,000 premature deaths were calculated in the capital based on annual average PM_{10} concentrations (BJEPB, 2006; Zhang et al., 2007b).

Sulfur Dioxide and Nitrogen Dioxide Concentrations

A large number of cities in China continue to be above the Chinese standard for sulfur dioxide and the WHO standard for nitrogen dioxide. WHO has not set a guideline for annual average levels of sulfur dioxide, but there is a daily average guideline of 20µg/m^3 (WHO, 2005).[5] In the 2006 rankings, 92 percent of China's cities had an annual average SO_2 concentration more than the WHO daily average guideline and would, therefore, likely exceed an annual average guideline were it to exist. The Chinese annual average standard for SO_2 is 60µg/m^3, a level which 30 percent of cities exceeded in 2005. Although no cities in China were above the current Chinese annual average standards for nitrogen dioxide of 80µg/m^3 in 2005, 22 percent were above WHO guidelines (and 1996-2000 Chinese standard) of 40µg/m^3.

These deteriorating trends in air quality are often blamed on local government protectionism, which permits rampant violation of pollution control laws (Xinhua, 2007b). Only about 500 of the 70,000 environmental violations reported from 2003-2005 had been dealt with by the spring of 2006, because local governments "actively encourage enterprises to violate environmental regulations and then protect them from punishment when they do" (Economy & Lieberthal, 2007).

API: WORST ENCOUNTER VS. AVERAGE ENCOUNTER

The API system used in China is based on the Air Quality Index (AQI) system used in the United

Table 2: API (China) and AQI (US) Health Effects and Colors

API CHINA	AIR QUALITY DESCRIPTION	REPORTED COLOR (BEIJING)	REPORTED COLOR (GUANGZHOU)
0-50	Excellent	Blue	Light Blue
51-100	Good	Green	Light Green
101-150	Slightly Polluted	Yellow	Yellow
151-200	Lightly polluted	Orange	Yellow
201-250	Moderately pol- luted	Red	Peach
251-300	Moderately-heavily polluted	Light Purple	Peach
>300	Heavily polluted	Brown	Pink

AQI U.S.	AIR QUALITY DESCRIPTION	REPORTED COLOR
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive groups	Orange
151-200	Unhealthy	Red
201-250	Very Unhealthy	Purple
251-300	Very Unhealthy	Purple
>300	Hazardous	Maroon

For the air quality to meet the WHO guidelines, the Air Pollution Index value for PM_{10} would need to be ≤ 50, for SO_2 it would be an API ≤ 20, and for NO_2 there is no daily guideline.

States (U.S. EPA, 2006). However, there is an important distinction that should be made: the U.S. AQI is based on the highest reading in a city, not an average as it is in China.[6] The result is that the AQI represent the "worst" case a person is likely to encounter; while the API in China represents the "average." Similar index systems exist in many other countries around the world; however, the United States and many other countries measure ozone and fine particulate matter ($PM_{2.5}$). For the air quality in China to meet WHO guidelines the API value for PM_{10} would need to be 50, and for SO_2 the API value would need to be 20. A value reported as a "Blue Sky" day with an API of 100 for PM_{10} would indicates a level of fine particulate three times WHO guidelines. Although the U.S. and Chinese systems have some similarities, they differ in describing how the level of pollution impacts health. Specifically, the Chinese API system uses more benign descriptions that often understate the levels of health threat. For example, an API of 151-200 is called "lightly polluted" in China, compared to "unhealthy" in the United States. (See Table 2 and Box 2).

Code Yellow or Good?

Another difference is that in the United States color designations and descriptions for different air quality levels are standardized, but in China local EPBs are able to determine the colors (if any) that are used to report air quality, and have frequently changing descriptions. For example, during the period of the 2008 Olympic Games the Beijing EPB went through three revisions on its website of how API values were described. Initially, API values from 51-100 were described as "good," then "moderate," then "medium," and finally to "Grade II." Post-Olympics, API values between 51 and 100 are again being described as "good" in Beijing—a code green day. In the United States, AQI values between 51-100 are described as "moderate"—code yellow.

Misleading Comparisons

Even though the API (China) is based on the AQI (U.S.), comparisons between the two systems are problematic. Because of the significant differences in the systems these comparisons can under represent the health threats from air pollution in China. In 2006, Los Angeles—often considered the most polluted city in the United States—did not report a single day where a single monitoring station exceeded the Chinese 24-hour PM_{10} standard of 150μg/m^3 (SCAQMD, 2007)[7]. In China, a PM_{10} concentration of this level is equal to an API of 100—still designated by the color blue in Beijing. In 2007, Beijing had 265 days where at least one of the monitoring stations in the city exceeded this level (Beijing EPB, 2007).

In Beijing, the number of days exceeding the Chinese hourly ozone standard was 101 in 1998

BOX 2. **Confusing Colors**

The metropolitan area in the United States with the highest annual average PM_{10} concentration during the 1990-1994 period was Visalia-Tulare-Porterville, California. The annual average PM_{10} concentration over these five years, based on a single monitoring station near a major road, was 60.4 μg/m^3. The highest daily average recording during these five years, at this, the most polluted monitoring station in the United States was 207 μg/m^3—a day that would have an API of 178 in China and be classified as "lightly polluted."

The Natural Resources Defense Council's report *Breath-taking: Premature Mortality Due to Particulate Air Pollution in 239 American Cities* estimated that approximately 64,000 premature deaths from cardiopulmonary causes could be attributed to air pollution each year in the United States based on an analysis of 1990-1994 data. The report ranked Los Angeles sixth worst out of 239 cities, its annual average PM_{10} concentration during the 1990-1994 period was 43.8 μg/m^3. New York City was ranked 76th out of 239 metropolitan areas, and its annual average PM_{10} concentration during this period was 28.8 μg/m^3. Although one monitoring station in New York reported one day where the PM_{10} concentration hit 130 μg/m^3 (equivalent to an API of 90 and a "good" classification in China), the highest reported value at the other 14 stations in New York over these five years was a 95 μg/m^3 (equivalent to an API in China of 72 and a "good" classification). Los Angeles' annual average PM_{10} concentration, which placed it in the bottom (most polluted) 5 percent of U.S. cities during the 1990-1994 period, would have been in the top (least polluted) 5 percent of Chinese cities during 2004. The worst air quality recorded at any of the 14 monitoring stations in New York between 1990 and 1994 was exceeded on over 70 percent of days in Beijing from 2003 to 2007. Simply put, the Chinese estimate of 281,361 premature deaths due to air pollution in 2004 (Zhang, et al., 2007a) used far more conservative calculations of the health impacts of air pollution than the 1996 NRDC report.

and 119 in 1999, and although that number decreased since the change in the hourly standard was revised from 160 to 200μg/m^3, there have still been 57-90 days per year above the standard from 2001-2005, with the highest hourly concentration on record being reported in 2005 (Duan et al., 2007). Again, ozone is not considered for the API reporting system, although a methodology does exist (U.S. National Academies & CAS, 2008). The Shanghai Environmental Monitoring Center has started trial reporting of daily ozone concentrations for four monitoring stations within urban areas of the city on their website (www.semc.com.cn). On May 14, 2008, the highest reported hourly concentration was 182μg/m^3, a level above the 1996 Chinese standard, but in accordance with the revised standard. Archived data is not currently available.

Miscalculations

The monitoring and reporting of air quality in China is performed in accordance with standards established by the MEP. The 2005 Automated Methods for Ambient Air Quality Monitoring (HJ/T 193-2005) governs the placement and methodology of stations (SEPA, 2005). The *Technical Rules Concerning Ambient Air Quality' Daily Report* specifies the procedures for reporting air quality (SEPA, 2000).

The daily API report is based on measurements made at selected monitoring stations within a city. Pollutant concentrations at these stations are measured from 12 noon the previous day to 12 noon on the day of the report, and the averaged 24-hour concentration for each pollutant for each monitoring station is then divided by the selected monitoring stations to determine each pollutant concentration for the day. These pollutant concentrations are not publicly released, but instead are converted into index values, of which the dominant pollutant is then widely reported.

The table of pollutant concentrations and equivalent API breakpoints is the same in the Chinese

In June 2008, Beijing authorities ordered a two-month ban on construction in the city to help guarantee cleaner air for the summer Olympic Games in August 2008. Photo Credit: Andrew Chang

and English versions of the technical regulations.[8] However, the sample calculation from pollutant concentrations to API values in the English version of the technical regulations contains a significant error that results in the under calculation of actual pollution levels. The discrepancies between the 1998-2000 and 2000-2007 breakpoints and reporting systems will be discussed following a description of the 2000 revisions to the national air quality standards.

Mobile Monitoring Stations

In addition to having high standards, monitoring stations in China have sometimes been shifted with drastic impacts on reported air pollution trends.[9] The monitoring station locations in Beijing had been constant during the 1998-2005 period, but in 2006 the two monitoring stations in high traffic areas were removed, and replaced with three non-traffic monitoring stations (CNEMC, 2006). Although there has been a reported 10.8 percent decrease in Beijing's annual average NO_2 level between 1998 and 2006, the two stations in traffic areas have reported annual average NOx concentrations 100 percent higher than the non-traffic stations (BJEPB, 1998). This indicates that all the reported decrease in NO_2 concentrations in Beijing from 1998-2006 may be due to the changing locations of monitoring stations. Furthermore, in 2008 Beijing began using three additional monitoring stations outside of the urban districts and beyond the sixth ring road to measure the city air quality, likely ensuring further "improvements" in air quality for all pollutants (Andrews, 2008c).

In Guangzhou, there has been a reported 3 percent decrease in NO_2 concentrations between 1999 and 2006; however, the lowest reported annual average concentration during this period occurred in 2000 (61 $\mu g/m^3$) and the overall decrease during this period may be suspect as well. *The New York Times* has suggested that Guangzhou and other cities may have also strategically placed monitoring stations in areas with below average pollution levels (Bradshear, 2008).

REVISIONS TO THE 1996 NATIONAL AIR QUALITY STANDARDS

China revised the 1996 National Air Quality Standards in 2000, but there appears to be some confusion on official websites and even among experts on the new standards. For example, two recent major publications relating to air pollution in China, *Costs of Pollution in China: Economic Estimates of Physical Damages* (World Bank & MEP, 2007), as well as *Energy Futures and Urban Air Pollution: Challenges for China and the United States* (NAS & CAS, 2008), both include errors in describing the Chinese National Ambient Air Quality Standards (CNAAQS). Specifically, these two publications both incorrectly state that the current daily (80$\mu g/m^3$) and annual average (40$\mu g/m^3$) standards for NO_2, which were the original standards established in 1996, not the less stringent revised standards that were set in

Table 3: API Breakpoints and Concentrations For Selected Pollutants

	AFTER JUNE 2000			BEFORE JUNE 2000		
	PM_{10} (μG/M³)	NO_2 (μG/M³)	SO_2 (μG/M³)	TSP (μG/M³)	NO_x (μG/M³)	SO_2 (μG/M³)
0-50	0-50	0-80	0-50	0-120	0-50	0-50
50-100	50-150	80-120	50-150	120-300	50-100	50-150
100-200	150-350	120-280	150-800	300-500	100-150	150-250
200-300	350-425	280-565	800-1600	500-625	150-565	250-1600
300-400	420-500	565-750	1600-2100	625-875	565-750	1600-2100
400-500	500-600	750-940	2100-2620	875-1000	750-940	2100-2620

Source: Technical Rules Concerning Ambient Air Quality Daily Reports (SEPA, 2000)

2000 when localities began measuring NO_2 instead of NOx (SEPA, 2000). At that time, the daily standard for NO_2 was raised to (120ug/m³) and the annual average standard was doubled to (80μg/m³).

China's MEP also does not include notice of the revised standard accompanying the description of air quality reporting on its website. The technical regulations governing the daily API reports included on the MEP website provides a link to the unrevised 1996 CNAAQS (SEPA, 2000). However, the MEP 2005 and 2006 *Annual State of the Environment* reports that all cities in China met the national NO_2 standard (SEPA, 2005 & 2006). Of the 108 cities included in the 2005 rankings, 22 percent exceeded the 1996 CNAAQS for NO_2, including many major cities.

In 2006, the annual average NO_2 concentration in Beijing was 66μg/m³ and in Guangzhou it was 67μg/m³ (BJEPB, 2007; GZEPB, 2007). Under the 1996 standards, Beijing and Guangzhou would have exceeded the annual average NO_2 standard in 2006 by 65 percent and 67 percent, respectively. Under the revised standards, both were in compliance (SEPA, 2000). In 1998, NOx was still used to gauge compliance with the 1996 CNAAQS. That year, Beijing and Guangzhou had the highest concentrations of NOx in China at 151 μg/m³ and 124 μg/m³, respectively (Ministry of Statistics, 1999). Beijing's annual average NOx concentration that year was over three times the permissible limit of 50μg/m³, and Guangzhou's was also far above the standard. For 1998, the annual average NO_2 concentration in Beijing was 74 μg/m³, 85 percent higher than the 1996 CNAAQS standard of 40 μg/m³ (BJEPB, 2002). Yet, the 1998 NO_2 concentrations for Beijing would be in compliance with the 2000 revisions to the 1996 CNAAQS. For 1999 (1998 data unavailable), the annual average NO_2 concentration in Guangzhou was 69μg/m³, 73 percent higher than the 1996 CNAAQS standard, but similarly, the air quality would have been in compliance under the 2000 revisions to CNAAQS.

CHANGES TO THE API REPORTING SYSTEM

In June 2000 when daily API reporting began, MEP made changes to the reporting system so that equivalent or roughly equivalent pollution concentrations were reported as having less of a health impact. (See Table 3.) This change also had a significant impact on the number of "Blue Sky" days being reported in cities.

- NOx/NO_2—From 1998-2000 an API of 100 was equivalent to a NOx concentration of 100. Beginning in 2000, an API of 100 was equal to a NO_2 concentration of 120 μg/m³. Although the NOx/NO_2 ratio varies, in Beijing the ratio was approximately 2/1 in 1998 and 1999.[10] An API of 100 from 1998-2000 indicating a concentration of NOx of 100 μg/m³ was approximately equal to an NO_2 concentration of 50 μg/m³. Under the 2000 revision, NO_2 concentrations twice as high at 120 μg/m³ are reported as an API of 100.

- SO_2—A pollutant concentration of 250 μg/m³ was equal an API of 200 between 1998-2000.

Figure 3:

Daily PM_{10} concentrations in Beijing at 22 monitoring stations with a record from 2003-2007. The graphed fit line indicates a normal distribution. A PM_{10} concentration of 150 μg/m^3 equals an API of 100. In 2003, an API right above or right below the API = 100, PM_{10} = 150 μg/m^3 breakpoint was of approximately equal likelihood. One clear indication of manipulated data in 2007 is the fact that 191 days were reported with an API of 100 (off the chart), and 0 days with an API of 101.

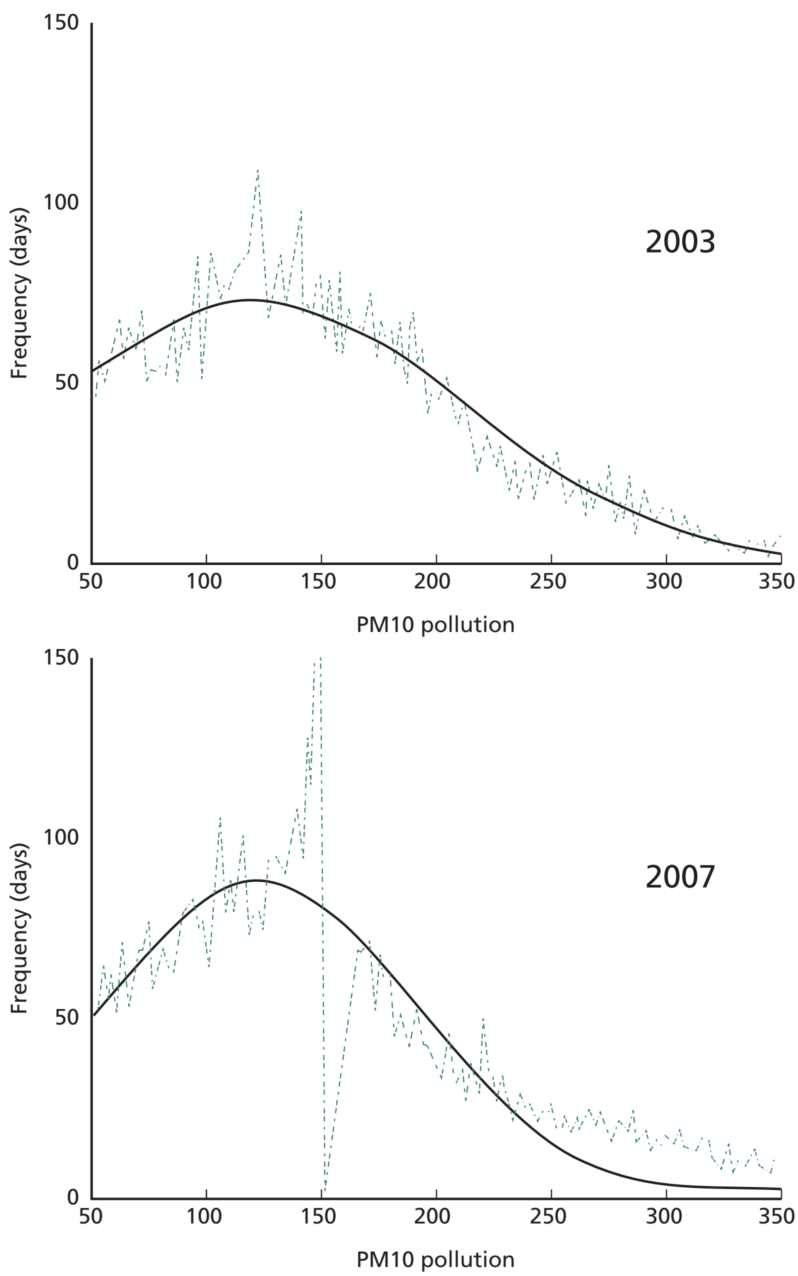


Table 4. Chinese Cities and Years With Largest Bias in Reporting Near the API = 100 National Standard

RANK	CITY	YEAR	# DAYS JUST BELOW STANDARD API 96-100	# DAYS JUST ABOVE STANDARD API 101-105	% DAYS WITH API = 96-105 MEETING STANDARD	API >105
#1	Chengdu (1)	2007	52	0	100%	46
#2	Xian	2007	48	0	100%	70
#3	Changchun	2006	23	0	100%	24
#4	Kunming	2006	22	0	100%	2
#5	Shenyang (1)	2003	77	1	98.7%	66
#6	Chongqing	2003	56	1	98.2%	127
#7	Chengdu (2)	2005	43	1	97.7%	70
#8	Shenyang (2)	2004	73	2	97.3%	63
#9	Shijiazhuang (1)	2006	36	1	97.3%	78
#10	Changchun (1)	2005	32	1	97.0%	24
#11	Suzhou (1)	2004	31	1	96.9%	59
#12	Changchun (2)	2004	29	1	96.7%	20
#13	Tianjin (1)	2002	28	1	96.6%	90
#14	Nanjing (1)	2003	54	2	96.4%	66
#15	Weinan	2004	27	1	96.4%	73
#16	Dalian	2006	26	1	96.3%	26
#17	Beijing (1)	2006	50	2	96.2%	123
#18	Nanjing (2)	2004	40	2	95.2%	69
#19	Kaifeng	2004	39	2	95.1%	65
#20	Hangzhou	2003	38	2	95%	70
#21	Shenyang (3)	2007	34	2	94.4%	39
#22	Anshan	2007	50	3	94.3%	68
#23	Suzhou (2)	2001	33	2	94.2%	33
#24	Shijiazhuang (2)	2003	46	3	93.9%	151
#25	Tianjin (2)	2003	42	3	93.3%	98
#26	Chengdu (3)	2006	54	4	93.1%	60
#27	Shenyang (4)	2006	50	4	92.6%	40
#28	Qingdao	2002	24	2	92.3%	29
#29	Shenyang (5)	2005	47	4	92.2%	44
#30	Beijing (2)	2007	57	5	91.9%	114

Parenthesis used to indicate respective ranking of cities that appear in the list multiple times. Note: Strikingly, while the bias in reporting is quite pronounced in many cities since the air quality standards were relaxed, many of the same cities did not experience any bias in the initial years of reporting. Potentially showing that the pressure to appear green got stronger as pollution problems increased, even after laxer standards. See list below:

#2 Xian (2000) reported 51.2% of 41 days with an API of 96-105 as meeting standard.
#5 Shenyang (2000) reported 57.1% of 28 days with an API of 96-105 as meeting standard.
#5 Chongqing (2001) reported 46.2% of 52 days with an API of 96-105 as meeting standard.
#9 Shijiazhuang (2000) reported 43.5% of 23 days with an API of 96-105 as meeting standard.
#11Suzhou (2002) reported 47.4% of 19 days with an API of 96-105 as meeting standard
#13 Tianjin (2001) reported 57.8% of 45 days with an API of 96-105 as meeting standard.
#17 Beijing (2001) reported 50.0% of 24 days with an API of 96-105 as meeting standard.

However, beginning with daily reports, an average SO_2 concentration of 250 μg/m^3 became equal to an API of 116.

- TSP/PM_{10}—From 1998-2000 a TSP concentration of 500 μg/m^3 was equal to an API of 200. A TSP concentration of 500 μg/m^3 corresponds to a PM_{10} concentration of approximately 250 μg/m^3. However, a PM_{10} concentration of 250 μg/m^3 has been equal to an API of 150 since the change in standards.

"BLUE SKY" BIAS

When asked by a reporter from *The New York Times* whether Beijing's tally of "Blue Sky" days was being manipulated, Du Shaozhong, the deputy director of the BJEPB responded: "People used to ask me whether the ratings are scientific, or if we are playing tricks. But this is the most advanced scientific equipment in the world" (Yardley, 2007). The likelihood of an API right below (API 96-100) or right above (API 101-105) the API = 100, national standard should be approximately equal. However, as many Chinese cities have now begun reporting air quality based on the number and percentage of days meeting the national standard, the annual "Blue Sky" tally has become increasingly important.

According to a 2001 description of the "Blue Sky" days for Beijing published in *Xinhua News Agency*, the environmental protection work is a very scientific process, with automated monitoring and calculating of air quality, so that there is no way that the numbers can be modified (Xinhua, 2001); however, "Blue Sky" trends show irregularities. Specifically, in Beijing, annual targets began being set in 2004 for individual monitoring stations, in addition to the annual city target (Beijing Municipal Government, 2004). In 2003, before the targets were set, there does not appear to be any bias in reported pollutant concentrations near the PM_{10} = 150 μg/m^3, API = 100 "Blue Sky" boundary. However, in 2007 there is a pronounced spike with a very large number of values being reported right below and at the boundary, and no numbers being reported right above. Daily averaged PM_{10} concentrations typically follow a log-normal distribution which is included in Figure 3 (WHO, 2005).

Although several articles have now raised questions as to whether Beijing has manipulated reported data near the "Blue Sky" boundary, no known study has examined other cities in China for possible irregularities (Andrews, 2008a,b,c; Ramzy, 2008; Yardley, 2008b). An analysis of daily API values from 2001-2007 for all cities in China with public reporting provides startling results. (See Table 4 and Figure 4).

The Blue Sky bias in Beijing is compelling for two reasons. First, neither the city nor the monitoring station API values appear to have a bias in the initial year of reporting. In 2001, Beijing reported 24 days in the API 96-105 range and 12 of them were reported as "Blue Sky" days. In 2003, the first year Chinese cities reported monitoring station data; API values of 100 or 101 for individual monitoring stations were approximately equally likely. In 2006 and 2007, there is a strong bias right near the API = 100 "Blue Sky" boundary in both the monitoring station and city data. Second, this apparent bias near the "Blue Sky" boundary is completely eliminated when calculating the daily air quality using the same monitoring stations that had been used in prior years (Andrews, 2008a). In the run-up to the Olympics, officials in Beijing were under great pressure to increase the annual number of "Blue Sky" days (Xinhua, 2007b). (See Box 3).

Beijing has received considerable news media attention regarding the reporting of API values near the "Blue Sky" boundary, but the irregularities seen in Beijing for 2006 and 2007 are far from the most pronounced (ranking as the 17th and 30th largest, respectively). Cities with a strong bias near the boundary are located in all geographic areas, and include some of the most and least polluted cities in China. Many of the cities that have the largest bias interestingly appear to have had no bias during the initial years of reporting, for example:

- *Xian, Shaanxi*. Xian reported 48 days in 2007 with an API of 96-101, and 0 days with an API of 101-105. In contrast, during the first year of public reporting in 2000, Xian had 41 days with an API of 96-105. 21 of these days were reported with an API of 96-100 and 20 were reported with an API of 101-105.

- *Chongqing Municipality*. In Chonqing, 55 days in 2003 were reported as having an API of 96-100, and 1 day with an API of 101-105. For 2001, 52 days were reported with an API in this same range right above and below the national standard from 96-105, and of these, 24 were reported as meeting the standard with an API of 96-100 and 28 were reported as barely exceed-

BOX 3. **Olympic Air Quality**

Hailie Gebreselassie, gold medal favorite in the men's marathon, brought international attention to Beijing's pollution with his announcement in March 2008 that he would not be competing because "the pollution in China [was] a threat to [his] health."[1] Then four U.S. cyclists sparked an international media storm when they arrived in the Beijing airport wearing gas masks just before the Olympics began.[2] Much to the relief of athletes and organizers, the air quality overall during the Olympics was relatively good. But the haze obscuring the capital in late July and early August, which lingered through the initial days of competition, and again appeared on several days following the closing ceremonies,[3] was not due to fog as the president of the International Olympic Committee and Chinese officials described.[4]

As the Games were about to begin, the Beijing Environmental Protection Bureau (BJEPB) downplayed the smog, insisting that "[w]e should judge whether there is pollution by scientific statistics, not by what our eyes can see."[5] The BJEBP was referring to many organizations taking pictures of daily air quality as a gauge of pollution levels,[6] partially the British Broadcasting Corporation (BBC)[7] and the Associated Press (AP),[8] which began taking their own readings of pollution levels in addition to daily photos. Notably, even the Chinese Ministry of Science and Technology (MOST) project (funded by the European Space Agency) that was forecasting daily pollution levels had predicted the air quality for the opening ceremonies would fail the Chinese standards. That same day, MOST insisted that the forecasts stop being made public for undisclosed reasons.[9]

On the day of the opening ceremonies, both the AP and BBC measured pollution levels above the Chinese national standard, but the BJEPB insisted that the air quality met the standard based on their own measurements.[10] On the second day of competition, a typically smoggy summer day in Beijing, one-third of the cyclists in the grueling 158-mile race failed to finish due to the heat, humidity and pollution.[11] The haze soon cleared, lowering the pollution hype by the news media and all the blue sky days during the Games would lead Gebreselassie to regret having pulled out of the marathon. Although it should be noted that the measurements—made by the BJEPB, AP, and BBC—of average daily pollution levels from August 8-24 were all above the daily World Health Organization guidelines.

Improving Beijing's air quality has been a challenging task that began in the mid-1990s in earnest by shifting the city's dependence on coal for heating to natural gas. Winning the Olympic bid in 2001 empowered the Ministry of Environmental Protection and the BJEPB to adopt more aggressive auto emission fuel standards than the rest of the country and to shut down hundreds of dirty factories in the city. As the Games approached temporary restrictions were enforced, such as banning heavy tucks from the city center and halting all construction projects in the city.[12] The request and then order for private car owners to restrict their driving was one of the largest public participation efforts of the Olympics. The campaign, called "Drive one less day a month so that the capital can have one more blue sky day," sought to put the blame for Beijing's pollution on the rapidly increasing number of car owners. Yet, not only does Beijing have far fewer cars overall than most developed countries, the emissions and fuel efficiency standards are actually better than those in many countries, including the United States.

"…not only does Beijing have far fewer cars overall than most developed countries, the emissions and fuel efficiency standards are actually better than those in many countries, including the United States."

Contrary to fears that Beijing would experience a drastic slide in air quality regulation and monitoring after the Olympics, the BJEPB announced in late 2008 that a total ban of heavily polluting trucks will begin in October 2009.[13,14] Even more crucial was the BJEPB announcement that it will start measuring ozone and fine particulate matter ($PM_{2.5}$) following the Games, which will hopefully lead to greater public understanding of Beijing's "fog." These new policies underscore that progress in keeping Beijing's air cleaner may not be reversed.[15] Hopefully the increased public awareness of air pollution threats will lead to more demands that Beijing's skies become even cleaner in the future.

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> **"Five out of 10 Chinese cities that had been ranked in 1998 as among the most polluted in China remained among the most polluted in 2006."**

ing the standard with an API of 101-105.

- *Chengdu, Sichuan Province*. Chengdu's reported API values in 2006 and 2007 had, respectively, the largest and seventh largest bias near the "Blue Sky" boundary of any city and year in China. Even with this bias, Chengdu, with 301 "Blue Sky" days in 2006 (84 percent) of the year, still ranked in the bottom (worst) 25 percent of Chinese cites. With substantially fewer days meeting the national standard in 2006 (34 less) and 2007 (17 less) than in 2001, officials in Chengdu have likely been under pressure to improve the air quality. Assuming that in 2007, half of the 52 days reported with an API of 96-105 had not actually met the standard, then Chengdu would have had 26 fewer "Blue Sky" days, and the air quality would have been the worst during the 2001-2007 period.

- *Kunming, Yunnan Province.* Kunming's reported API values for 2006 are found to have had the sixth largest bias. This is unexpected, because Kunming has some of the best air quality in China. With only three days above the national standard in 2006, Kunming was ranked ninth of 108 cities placing it in the top 10 percent nationally. However, assuming that for 2006, of the 22 days reported with an API of 96-105, half had not actually met the standard, Kunming would have had 11 fewer "Blue Sky" days. This would have dropped Kunming 15 rankings to 24th place, and the air quality would have tied for worst during the 2001-2007 period.

Although at least one Chinese city has been criticized by MEP for moving monitoring station locations in order to report "cleaner" air (*Environment News*, 2006), MEP has not publicly criticized Beijing. Research has found that changes in Beijing's monitoring station locations on January 1, 2006, and further changes on January 1, 2008, have had significant impacts on the reported number of "Blue Sky" days (Andrews, 2008a,b,c). BJEPB has reported that these 2006 changes at least were done in accordance with national regulations (*Sydney Morning Herald*, 2008). In his piece examining the dynamics of local governance, Cai Yongshun (2000, p.786) observed, "[w]hile some officials achieve success based on their achievements, some do so by manipulating statistics. This phenomenon is called 'good statistics lead to promotion' (*shuzi chu guan):* officials get promoted by over-reporting their achievements and under-reporting their failures. They can also pressure lower-level officials to report fake statistics (*guan chu shuzi*)." According to MEP's Minister Zhou Shengxian, "those who fabricate [environmental indices] will be dealt with appropriately" (Xinhua, 2007a), but China's underfunded environmental watchdog and its local bureaus have faced considerable difficulties in punishing the rampant problem of local government manipulation of environmental data. The May 2008 Environmental Information Disclosure Measures may, however, help MEP in this regard, for it aims to create more transparency around all pollution-related data.

RANKINGS OF CHINESE CITIES UNDER API

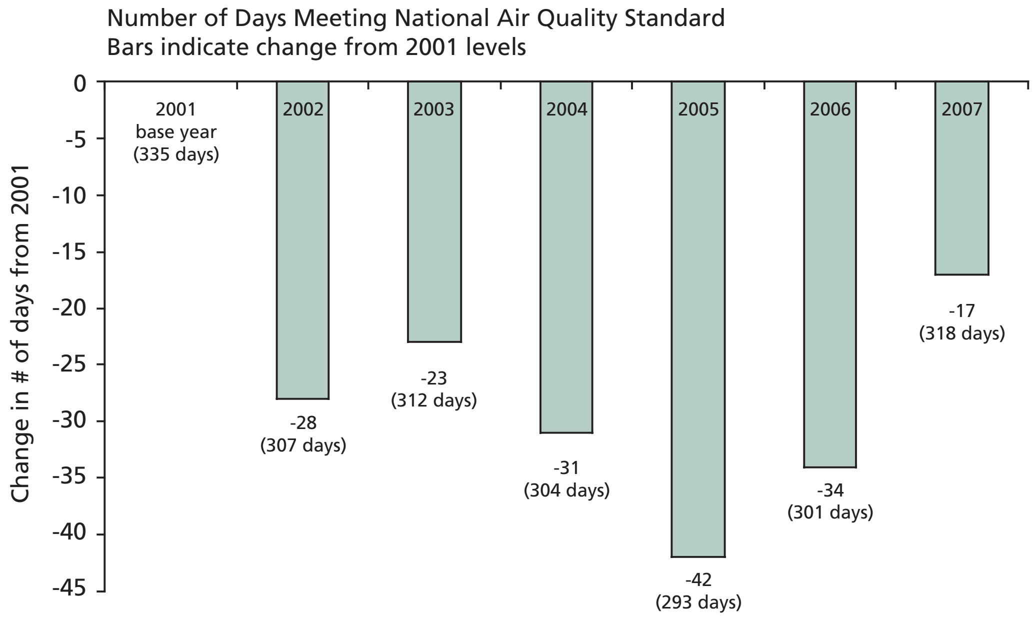
Rankings in China are very significant for the evaluation of government officials. In 1998, cities were ranked according to a total index (*zonghe wuran zhishu)*—not to be confused with the weekly/daily API. In 1998, Beijing was ranked as having the third worst air quality with a total value of 6.898. This was calculated in the following manner:

- The annual average NOx concentration in 1998 was 151μg/m^3, and the annual average standard was 50μg/m^3. So Beijing's annual average NOx concentration was 3.02 times the annual average standards.

- The annual average TSP concentration in 1998 was 378μg/m^3, and the annual average standard was 200 ug/m3. Beijing's TSP level was 1.89 times the standard.

- The annual average SO_2 concentration in 1998 was 120μg/m^3, and the annual average standard

Figure 4: Chengdu Air Quality Reporting



was 60μg/m^3. Beijing's SO_2 level was 2.0 times the standard.

- The 3.04 times NOx standard + 1.89 times TSP standard + 2.0 times SO_2 standard equals 6.89—Beijing's comprehensive API for the year.

- The comprehensive API values for other cities were calculated in the same manner (See Tables 5 & 6).

In 2006, Chinese cities were ranked according to the annual number of days meeting the national standard. Ranking cities according to the number and percentage of days meeting the national standard has also been used as one of the primary indicators of air quality in the United States (U.S. EPA, 2003). Five out of 10 Chinese cities that had been ranked in 1998 as among the most polluted in China remained among the most polluted in 2006. These include the following: Beijing, Datong, Urumqi, Lanzhou and Taiyuan. However, comparing the total index values between 1998 and 2006 is problematic for two main reasons. First, as noted previously, Beijing was over three times the annual average NOx standard in 1998, but in compliance with the revised NO_2 standard. Therefore, using NO_2 instead of NOx results in significantly lower total index values. Second, the relationship between TSP/PM_{10} concentrations and the TSP/PM_{10} standards also affects the reported index. (See Tables 5 and 6).

SEEING THROUGH THE SMOG

Air Quality Trends in 5 Major Cities

Analysis of annual average PM_{10}, NO_2, and SO_2 levels from 2000-2005 in five major cities does not indicate any clear trends in air quality. The five cities, indicated in figures 5-7, had the five highest annual average concentrations of NOx in 1998: Beijing (151μg/m^3); Guangzhou (123μg/m^3); Shanghai (100 μg/m^3); Wuhan (94 μg/m^3); and Urumqi (87 μg/m^3). All five of these cities exceeded the 1996 annual average NO_2 standard of 40ug/m^3 for all six of these years, but all of the cities have consistently been in compliance with the revised 2000 annual average NO_2 standard of 80μg/m^3. The cities had annual average PM_{10} concentrations above the national standard (100μg/m^3) in 2001 and continued to exceed the national standard in 2005. Beijing and Urumqi have had a decrease in annual average SO_2 concentrations during this period, but Guangzhou, Shanghai and

Table 5. 10 Most Polluted Cities in China—1998 SEPA Rankings (1998 Data, μg/m³)

RANK	CITY	TOTAL INDEX	TSP STANDARD - 200	NOX STANDARD - 50	SO_2 STANDARD -60
#1	Taiyuan	8.41	523 (2.62x)	66 (1.32x)	276 (4.6x)
#2	Shizuishan	7.06	741 (3.71x)	---	145 (2.42x)
#3	Beijing	6.90	378 (1.89x)	151 (3.02x)	119 (1.98x)
#4	Urumqi	5.90	504 (2.52x)	87 (1.74x)	104 (1.73x)
#5	Jilin	5.75	560 (2.8x)	81 (1.62x)	80 (1.33x)
#6	Datong	5.56	594 (2.97x)	---	117 (1.95x)
#7	Lanzhou	5.49	632 (3.16x)	65 (1.3x)	---
#8	Zibo	5.49	---	59 (1.18x)	142 (2.27x)
#9	Yibin	5.34	249 (1.25x)	59 (1.18x)	175 (2.92x)
#10	Chonqing	5.34	---	56 (1.12x)	183 (3.05x)

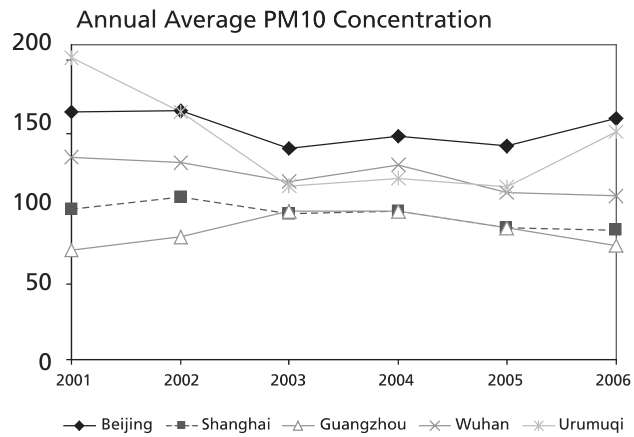
Source: Ministry of Statistics, 1999
Parentheses indicates how many times city value was above national standard
Note: Daily reporting did not being until June 2000.

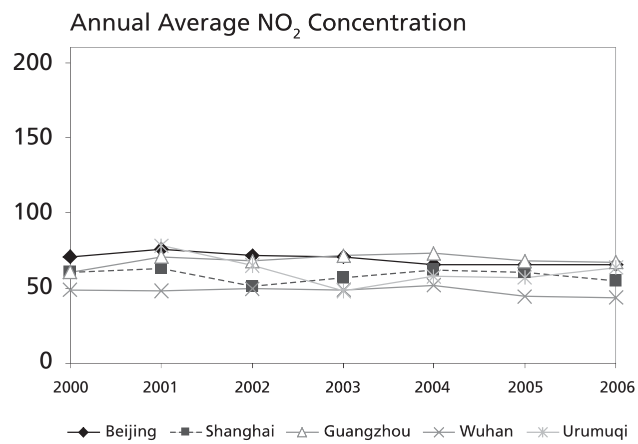
Table 6. 10 Most Polluted Cities in China—2006 SEPA Rankings (2006/2005 Data, μg/m³)

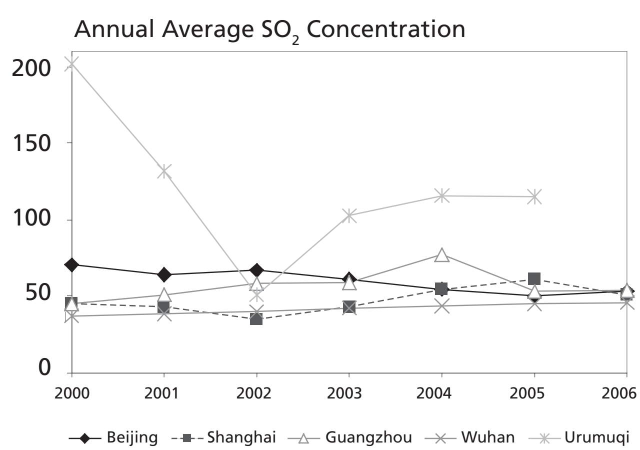
RANK	CITY	% DAYS WITH API ≤100	PM_{10} STANDARD 100	NO_2 STANDARD 80	SO_2 STANDARD = 60	TOTAL INDEX*
#1	Linfen	53.54%	184 (1.84x)	54 (0.68x)	177 (2.95x)	5.47
#2	Lanzhou	56.16%	157 (1.57x)	38 (0.48x)	68 (1.13x)	3.18
#3	Datong	65.48%	154 (1.54x)	37 (0.46x)	96 (1.60x)	3.60
#4	Beijing	66.03%	142 (1.42x)	66 (0.83x)	50 (0.83x)	3.08
#5	Urumqi	67.40%	115 (1.15x)	56 (0.70x)	117 (1.95x)	3.80
#6	Jinchang	68.77%	92 (.092x)	24 (0.3x)	112 (1.87x)	3.09
#7	Yueyang	69.90%	143 (1.43x)	26 (0.33x)	48 (0.8x)	2.55
#8(tie)	Weinan	71.50%	146 (1.46x)	46 (0.58x)	83 (1.38x)	3.42
#8(tie)	Xiangtan	71.50%	126 (1.26x)	38 (0.48x)	64 (1.07x)	2.80
#8(tie)	Pingdingshan	71.50%	147 (1.47x)	43 (0.59x)	67 (1.12x)	3.12
(#11)	Taiyuan	71.51%	139 (1.39x)	20 (0.25x)	77 (1.28x)	2.92

% Days with API ≤ 100 is for 2006, all pollutant concentrations are for 2005
*Note: Total index stopped being used in 2003.
Source: SEPA, 2007

Figures 5-7







Note: All pollutant concentrations are in µg/m3 Sources: Shanghai EPB 2002-2006; Guangzhou EPB 2002-2006; Wuhan EPB 2001-2006; BJEPB 2002-2006; He & Chang 2000 [Urumqi data].

Wuhan have all had increases. Although there appears to be some improvements for some cities in some years, there do not appear to be any nationwide, sustained improvements.

Long-term trends are difficult to determine from MEP's composite *State of the Environment* reports, which usually do not differentiate between the number of cities included in annual national statistics. For instance, the 2007 *Economic Costs of Pollution* contains figures showing the long-term trends in major cities in China for TSP, SO_2, and NOx from 1980-2004 accompanied by the following disclaimer: "The averages in each year are arithmetic average—unweighted by population—of available readings for 'major cities.' The set of cities varies from 53 to 97, depending on the year" (World Bank, 2007). In MEP's *1997 Report on the State of the Environment* it was reported that 28 percent of the 93 monitored cities met the national standard for particulate (SEPA, 1997). In the *2006 Report on the State of the Environment* it was reported that 62.4 percent of the 559 monitored cities met the national standard for all pollutants (SEPA, 2006). However, it is unclear what 93 cities were monitored in 1997 and what percentage of these cities met the air quality standard in 2007. Furthermore, changes in the pollutants monitored (NO_2/NOx and TSP/PM_{10}) and the 2000 revisions of the national standards further complicate any comparisons that may be made between these numbers.

Satellite Imagery and Remote Sensing Studies

Although publicly reported annual average concentration of nitrogen dioxide appears to be relatively constant for major Chinese cities, studies that have been done using satellite imagery have found significant increases. A major study published in *Nature* analyzing 1996-2004 data found an increase of approximately 50 percent for nitrogen dioxide concentrations over the industrial areas of China (Richter et al., 2005). This study prompted the international news media to dub Beijing the "pollution capital of the world" (Watts, 2005). Other research similarly found through analysis of satellite imagery that the emissions calculated for NOx, derived using data from the *China Energy Statistics Yearbook* were considerably underestimated (Akimoto et al., 2006).

AIR QUALITY REPORTING AND PUBLIC PARTICIPATION

According to Pan Yue, deputy director of MEP, "people should participate more than planting trees or cleaning rubbish. They should join the policy-making." He observed that for this greater public involvement to happen, relevant departments and enterprises must publish their environmental information (Xinhua, 2007d).

In 1997, *China Environment News* published a series of reports on vehicle emissions, representing the first public disclosure of the air pollution that results from leaded gasoline. These reports raised public awareness, and resulted in government officials examining ways to ban leaded gasoline in urban areas leading the head of MEP to comment that environmental protection in China will only be successful with the assistance of the mass media (Bo, 1998).[11]

In Beijing, one of the largest campaigns has been a public interest environmental activity to encourage car owners to drive one less day so that the capital can have one more "Blue Sky" day a month (Xinhua, 2006). This campaign appears to be placing the responsibility for the city's air quality problems on the one group that has the greatest ability to actually pressure government officials—the rising middle class. However, in the transport sector a larger pollution source is diesel consumption, which is twice as high as gasoline use and is much dirtier and growing faster in China (National Bureau of Statistics, 2006). Tests done by Chinese and U.S. researchers in Tianjin found that diesel engines in trucks and buses accounted for 93 percent of all nitrogen oxides from vehicles in China, and 97 percent of particulate (Bradsher, 2007).

Recent efforts by the Chinese NGO Institute of Public and Environmental Affairs (IPE) to develop China's first online water and air pollution maps represent a notable step towards making environmental quality information more accessible to the public. [*Editor's Note: See Spotlight Box on IPE by Boyle and Chen in this issue of CES*]. However, the air pollution website is hampered by many of the issues discussed in this paper: irregularities in monitoring and reporting of air quality, the 2000 revisions of the 1996 air quality standards, and a lack of access to information (IPE, 2008). One notable omission on the website is that no data for Beijing is included on any of the websites rankings of air quality in China.

> **"Although daily reports inform the public about air pollution levels, these reports have understated the impacts of air pollution on human health."**

In the United States, the push from NGOs has been instrumental for greater air pollution controls (American Lung Association, 2008). As noted in Box 1, the 1996 report by the U.S.-based Natural Resources Defense Council (NRDC), titled *Breath-taking: Premature Mortality Due to Particulate Air Pollution in 239 American Cities,* illustrated the importance of U.S. NGOs in promoting greater attention to air pollution and health problems. NRDC estimated that approximately 64,000 premature deaths from cardiopulmonary causes could be attributed to air pollution each year in the United States based on an analysis of 1990-1994 data. Given that China has a population over four times that of the United States, the estimated 281,361 premature deaths due to air pollution in China for 2004 (Zhang, 2007a) appears rather low.

Although air quality in the United States has improved since the 1990-1994 period, the latest report—*State of the Air: 2008*—by the American Lung Association started with the shocking statistic: "Two out of every five people—42 percent—in the United States live in counties that have unhealthful levels of either ozone or particulate pollution. Almost 125 million American live in 215 counties where they are exposed to unhealthful levels of air pollution" (American Lung Association, 2008). With Chinese air quality far worse then the United States, a crucial question is whether (and when) comparable reports will begin to be published in China. Accurate information is needed for the Chinese public to realize the true impacts of air pollution on human health.

A CALL FOR GREATER TRANSPARENCY

Transparency regarding environmental information in China has been markedly increasing since the mid-1990s. Public reporting of air quality began following the 1996 *State Council Decision on Environmental Protection* as part of a deliberate strategy to encourage citizens to put pressure on local governments to enforce environmental regulations (U.S. Embassy, 1998). In 2006, the message from Zhou Shengxian, the minister of MEP remained the same: "environmental indices will be published for public supervision" (Xinhua, 2007a). In May of 2008, the National People's Congress passed *Regulations on Government Disclosure of Information*, a comprehensive freedom of information legislation. MEP will implement the environmental aspects of this freedom of information legislation through *Measures of Environmental Information*, which was also adopted in May 2008. These new measures will help push transparency into government law, regulations, standards, and information on environmental quality. Some Chinese environmental NGOs, such as the Institute of Public and Environmental Affairs have been taking advantage of this growing openness in information, but they too suffer from poorly collected data techniques and independently collecting such data could be politically sensitive and is often impractical.

Despite the progress made in opening up access to environmental information, there still a lack of transparency in Chinese environmental statistics, which makes it difficult to ascertain the true state of Chinese air quality and analyze reported trends. Although daily reports inform the public about air pollution levels, these reports have understated the impacts of air pollution on human health. A day on which particulate concentrations are three times WHO guidelines can still have an API as high as 100 and be classified as "good." A day on which particulate concentrations are five times WHO guidelines can still have an API as high as 150 and still be classified as "slightly polluted." A day on which particulate concentrations are seven times WHO guidelines can still have an API as high as 200 and still be classified as "lightly polluted." Not a single one of the 108 cities included in MEP's 2006 city rankings achieved WHO guidelines for annual average particulate concentrations.

Transparency in public reporting has been further hindered as China weakened its air quality standards in 2000; at a time when other countries and WHO have been setting more stringent guidelines (Luo, 2007). Not only were the standards changed, but equivalent concentrations of NO_2/NOx, TSP/PM_{10} and SO_2 began being reported as having lower API values—indicating less significant health impacts when daily reporting began in June 2000. Although the calculation methodologies to go from API values to pollutant concentrations are straightforward, an error in the sample calculation on the MEP website has lead to misunderstandings of the true severity of pollution levels—inaccuracies that have been replicated in several leading reports on air pollution in China. Although the establishment of "Blue Sky" targets and well-publicized tallies of the number of days meeting the national standard has resulted in an easily understood metric for air quality, it strongly appears that pollution levels near this boundary are being manipulated in many major cities.

In 1997, air quality information was first publicly released as part of deliberate strategy by the central government to put pressure on local government officials to enforce national regulations. In 2006, government officials continued to state that environmental information is published for "public supervision." However, without accurate and transparent public reporting on the atmospheric environment, the public's ability to fulfill this role will continue to be largely diminished.

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NOTES

1. WHO also established last stringent interim targets to assist developing countries in tracking progress over time in reducing population exposure to pollution. The WHO interim target-1 for daily PM_{10} concentrations is 150 μg/m³ and the WHO interim target-1 for annual

PM10 concentrations is 70 μg/m^3. According to the WHO if more than 3 days have particle concentrations above 150 μg/m^3 the country has failed the interim-1 target, so even though China's daily PM_{10} standard is the same as the WHO PM_{10} interim-target 1, the interpretation is quite different, as China considers compliance with the daily standard on a daily rather than annual basis.

2. MEP has developed a methodology for including ozone concentrations in API reporting, and there has been limited public reporting in selected cities.

3. With a confidence interval from approximately 300,000 to 500,000 premature deaths per year.

4. Technically, WHO publishes air quality guidelines and not standards. However, consistent with statements by Chinese government officials and reports in Chinese publications, this article uses the terms guidelines and standards interchangeably. (See for example: Press conference: Beijing air quality, official website of the Beijing Olympic Games, August 8, 2008. Available: http://en.beijing2008.cn/live/pressconference/mpc/n214514906.shtml

5. While WHO does not provide a recommended annual SO_2 concentration guideline, when an annual guideline is provided for a pollutant, the guideline is generally much lower than the daily standard.

6. Some U.S. cities also include average API values, but maximum API values (from individual monitoring stations) are used to calculate the number of days failing the national standards. Although some Chinese cities report individual monitoring station data, this data is not widely used in evaluating air quality.

7. Note that according to the EPA Extreme Event Regulations high wind days are excluded from compliance consideration.

8. The Chinese and English versions of the SEPA technical regulations were removed from the MEP website prior to the Olympics in spring 2008 and currently remain unavailable online (2/1/09).

9. Note that not all monitoring stations are used in calculating the city air quality (Andrews, 2008b,c).

10. In 1998 and 1999 the annual average NOx concentrations for Beijing were 151μg/m^3 and 140 μg/m^3 and the annual average NO_2 concentrations were 74 μg/m^3 and 77 μg/m^3. This gives an approximate NOx/NO2 ratio of 2/1 (2/0.98 in 1998 and 2/1.1 in 1999) (BJEPB 1999)

FEATURE BOX

Water and Environmental Health: BSR Takes Action to Break Southern China's Water Crisis

By Linda Hwang

Since 1992, Business for Social Responsibility (BSR) has been working with companies to integrate social and environmental responsibility into their corporate strategies. In 1995, BSR began work with apparel and manufacturing companies to reduce environmental impacts in the textile and apparel industry. Wastewater from dye baths is often rated as the most polluting among all industrial sectors. The pollution load is characterized by high color content, suspended solids, salts, nutrients, as well as toxic substances such as heavy metals and chlorinated organic compounds.

More than a dozen leading companies—including Nike, Gap, and Levi Strauss & Company—were successfully recruited to form a working group to discuss impacts to water resources within their supply chains. The group found that: (1) no comprehensive or consistent global policy or regulation existed to effectively manage supplier and company practices and expectations related to wastewater quality, and (2) regulation and enforcement for water quality varied from country to country. BSR and the companies recognized an opportunity to reduce environmental impact through the development of global water quality guidelines, supported by the textile and apparel industry. The working group developed these guidelines and today they are embedded within a *Supplier Training Manual* developed by BSR, which also includes a set of recommendations for collecting, testing and treating wastewater. This manual is currently being used by textile mills, laundries, and dye factories in southern China's Guangdong Province, which supply a number of global apparel and retail brands.

In Guangdong Province, a growing population, ongoing industrialization, and inefficient industrial use of water have significantly increased demand on water resources. In 2005, the majority of pollution complaints received by the Guangdong Environmental Protection Bureau were related to water pollution. Coupled with the fact that Guangdong is responsible for 13 percent of China's economic growth, the availability of freshwater has become the crucial factor for the future growth of the region and for China as a whole. Now more than ever is sound management of Guangdong's water resources critical for sustainable development in China.

WATER QUALITY IMPACTS ON PEOPLE AND ECOSYSTEMS

More than 700 million people in China suffer from sanitation conditions that fail to meet World Health Organization global standards, and a quarter of the country's total population lacks access to clean drinking water. Based on China's 2003 National Health Survey, the World Bank estimates that China has 9 million cases of diarrhea linked to water pollution annually; the Organization for Economic Co-operation and Development reported in 2007 that nearly 61,000 people die from diarrhea due to polluted water each year—half of which are rural children. According to the Stockholm Environment Institute and the UN Development Programme, deaths from liver cancer—which is associated with high levels of inorganic substances in surface water—have doubled since the 1970s. China now has the highest liver cancer death rate in the world. As the following reports show, health problems from unclean water are particularly severe in Guangdong Province:

- The *Nanfang Daily* reported in 2008 that 12.62 billion tons of "polluted materials" and 8.3 billion tons of wastewater were discharged into the waters off Guangdong in 2007, up 60 percent from the five years earlier.

- According to Guangdong officials, more than 40 percent of the province's rural inhabitants do not have access to safe drinking water.

- The Dong River—a major source of water for Hong Kong—has shown a steady increase in ammonia levels over the last 10 years, with certain sections of the river becoming unsuitable for human consumption.

> **"Now more than ever is sound management of Guangdong's water resources critical for sustainable development in China."**

In addition to its impacts on human health, water quality and quantity also influences biodiversity—an essential component of maintaining the structure, function, and resilience of ecosystems. As biodiversity diminishes, there is a related decline in the performance of ecosystem services, such as the collective benefits of clean water, air, and timber. In other words, poor water quality can impair fundamental cycles that are needed to provide clean water, clean air and productive soils in functioning ecosystems and healthy economies. Forest rehabilitation efforts in Guangdong have a high potential to enhance biodiversity and reduce surface runoff of water and soil leaching, leading to reductions in the flow of harmful chemicals into lowland areas, particularly local water sources.

CHALLENGES IN MANAGING SOUTHERN CHINA'S WATER RESOURCES

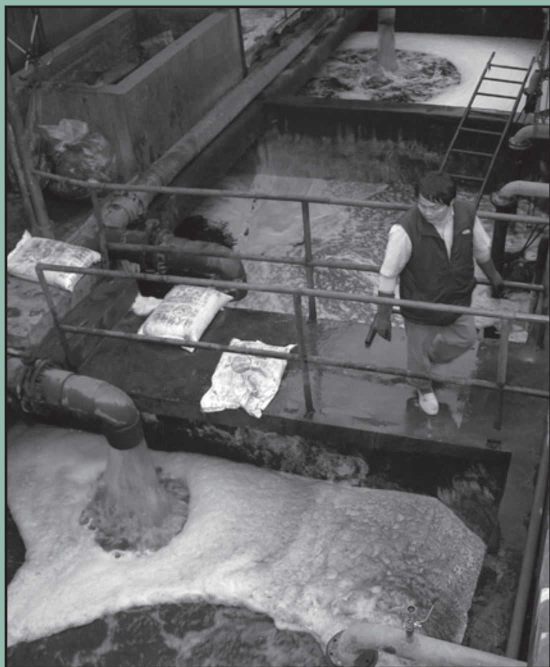
By some estimates, China may grow from its current population of 1.3 billion to 1.6 billion people in 2030. With increasing economic development, a higher standard of living, shifting eating habits, and almost half of the population living in urban areas, China's water resources will become increasingly scarce.

A second challenge relates to lack of information regarding best practices for suppliers' water management operations, as well as oversight and control at the factory level. BSR's research and work with factory managers has found that water management is not a pressing concern for factories, and that current involvement from global apparel and retail brands may partially contribute to that attitude. The primary contributors to this predicament are (1) inconsistency of brand monitoring and enforcement programs, (2) lack of knowledge among factories about the economic and environmental health benefits of sound water management practices, and (3) insufficient sharing of best practices for managing water usage and wastewater discharge among apparel retail brands and factories.

Lastly, though many research studies have examined this region's water quality management, few initiatives have considered the role of the private sector in reversing the degradation of water resources. Six industries account for about two-thirds of all industrial water demand: electric power, iron and steel, petroleum production and refining, chemicals, papermaking, and textile dyeing. Multinational organizations headquartered outside of China, Chinese companies with global operations, as well as local companies all have a part to play, but none have effectively engaged China's water resource management problems. Nonetheless, options are plentiful, including more sustainable management of supply chains, increasing water efficiency in operations, direct engagement with local stakeholders, and investments in the ecosystem services that affect water quality and availability.

BSR'S SOLUTIONS FOR CHINA'S WATER CRISIS

To address regulatory, technical and capacity barriers, in July 2008, BSR launched the Water and Environmental Health: Building Constituencies in Southern China project to focus on water quality, as well as the health of workers and the surrounding environment. This two-year project, made possible with generous support from the Rockefeller Brothers Fund, leverages BSR's China Training Institute (CTI), offering extensive experience in supply-chain management as a platform to support



Aeration and biological treatment at a wastewater treatment plant in Guangdong Province.
Photo Credit: Business for Social Responsibility

these efforts. CTI seeks to improve management practices of consumer product suppliers by delivering training to factory management that promote sound labor and environmental practices in Chinese export facilities; it will allow BSR to target areas where there has been minimal progress but where action by global companies will produce the most significant impacts.

From its China headquarters in Guangzhou, China, BSR's Water & Environmental Health program will consist of three major initiatives:

1. WATER MANAGEMENT IN CHINA'S APPAREL AND TEXTILE SECTOR

Building on existing relationships with members of the Sustainable Water Group and their suppliers, BSR is working with mills, laundries and dye houses to better understand water management at the factory level by conducting a comparative study on water quality management in a dozen Guangdong factories. The results of the study will be incorporated into the design and development of a customized, web-based, water information database for factory managers. The study's results will also be used to develop CTI's water management curriculum. BSR's work with multinational corporations and their suppliers is aimed at establishing long-term systemic change to improve water management practices in this sector in southern China. Findings and activities from this sector are being applied to other industries operating in the region.

2. WORKER ENGAGEMENT IN WATER QUALITY, SANITATION AND HYGIENE

Many factories in southern China include onsite dormitories that can house up to 20,000 workers. It is possible to deliver water quality, sanitation and hygiene education to worker communities while strengthening the capacity of local NGOs to act as service providers. BSR's aim is to develop a program that incorporates experiences from HERproject (www.herproject.org)—a program that delivers women's reproductive health education via peer-to-peer training—to help factory managers and workers understand the link between water quality and health.

3. STAKEHOLDER ENGAGEMENT FORUMS

Finally, BSR will present its findings at two forums in Guangzhou to build the link between water quality and environmental health in southern China. As the capstone component of BSR's proposed work with the Rockefeller Brothers Fund, the forums will ensure alignment between key stakeholders from the private sector, Chinese government, local and international NGOs, and academia. The first forum, a stakeholder engagement, will identify critical factory successes that have led to increased water efficiency, water reuse and sound management of wastewater, in addition to helping participants understand their respective roles and activities needed to build awareness and long-term capacity to improve water quality, ecosystems and human health. The second forum will create a broad network of actors at the intersection of water and health who can continue to self-organize after the formal BSR project concludes in 2010.

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