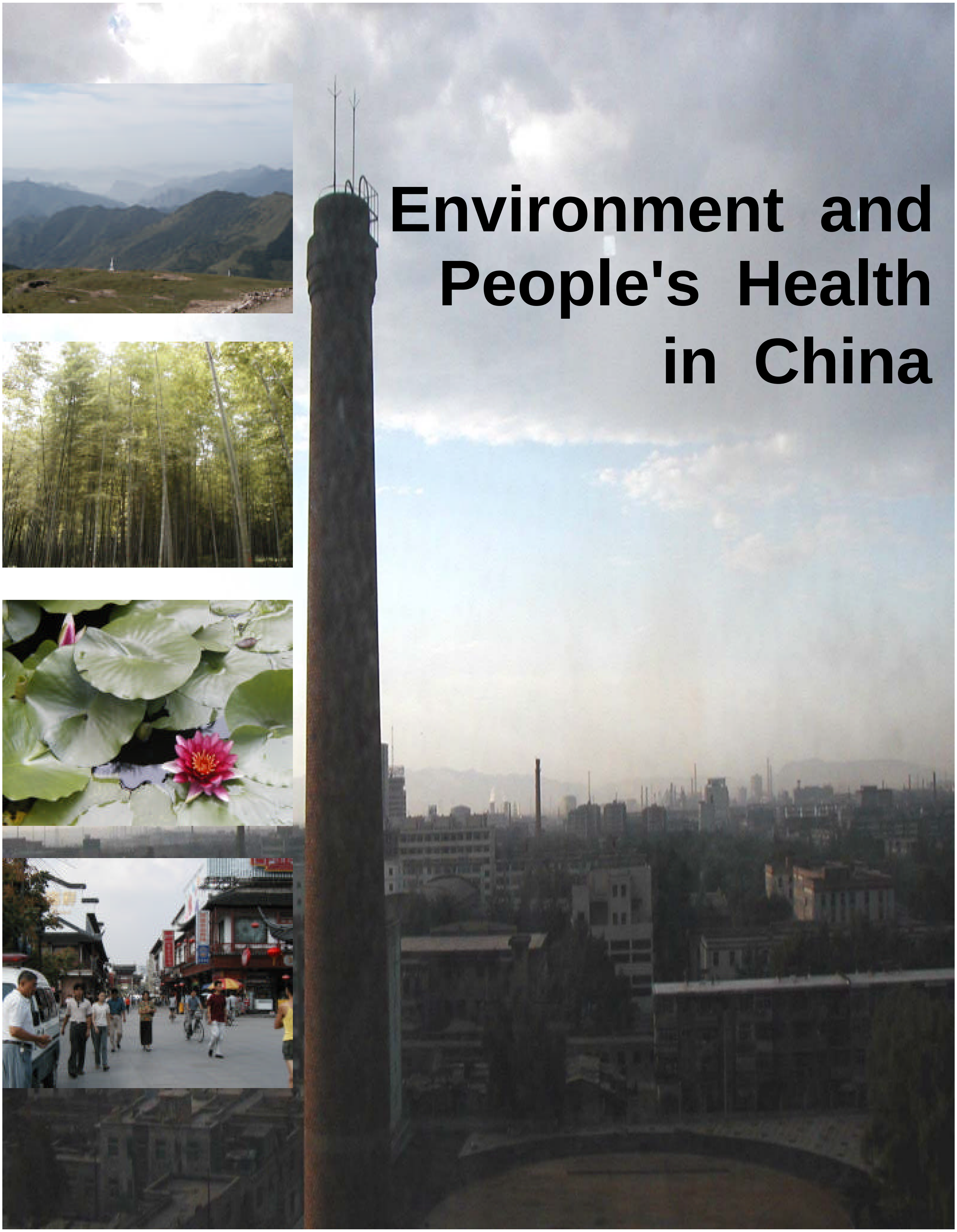
Environment and People's Health in China



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Abbreviations and Acronyms

API	Air Pollution Index
As	Arsenic
BaP	Benzo(a)-pyrene
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
COPD	Chronic Obstructive Pulmonary Diseases
Cr	Chromium
DSP	National Disease Surveillance Point System
F	Fluoride
GDP	Gross Domestic Product
GLM	General Linear Model
HC	Hydrocarbons
MOH	Ministry of Health
Mtce	Million Tonnes of Coal Equivalent
NOx	Nitrogen Oxides
OR	Odds Ratio
Pb	Lead
PM_{10}	Particulate Matter with Diameter Less Than 10 Microns
$PM_{2.5}$	Particulate Matter with Diameter Less Than 2.5 Microns
RR	Rate Ratio
SEPA	State Environmental Protection Administration
SMR	Standardization Mortality Rate
SO_2	Sulphur Dioxide
TSP	Total Suspended Particulate
TVE	Town Village Enterprise
UNDP	United Nations Development Program
WB	World Bank
WHO	World Health Organization
WRI	World Resource Institute
PLLY	Potential Lost Life Year

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Chapter 1
Linkage Between Health, Environment, and Socio-economic Cost

1.2 Introduction

Human health is closely tied to environmental conditions. The quality of air, water, and food resources within a country influences the health and potential exposure of the population to environmental health risks. An awareness of the relationship between the environment and human health is essential to improving the health of current and future populations.

Environmental degradation has contributed to declining health in many countries. In China, there is little information available on the impacts of environmental pollution on health, which becomes a constraint to environmental protection and in achieving sustainable development. It is therefore important to understand the impacts of development activities on the environment and eventually to public health for better planning and decision-making.

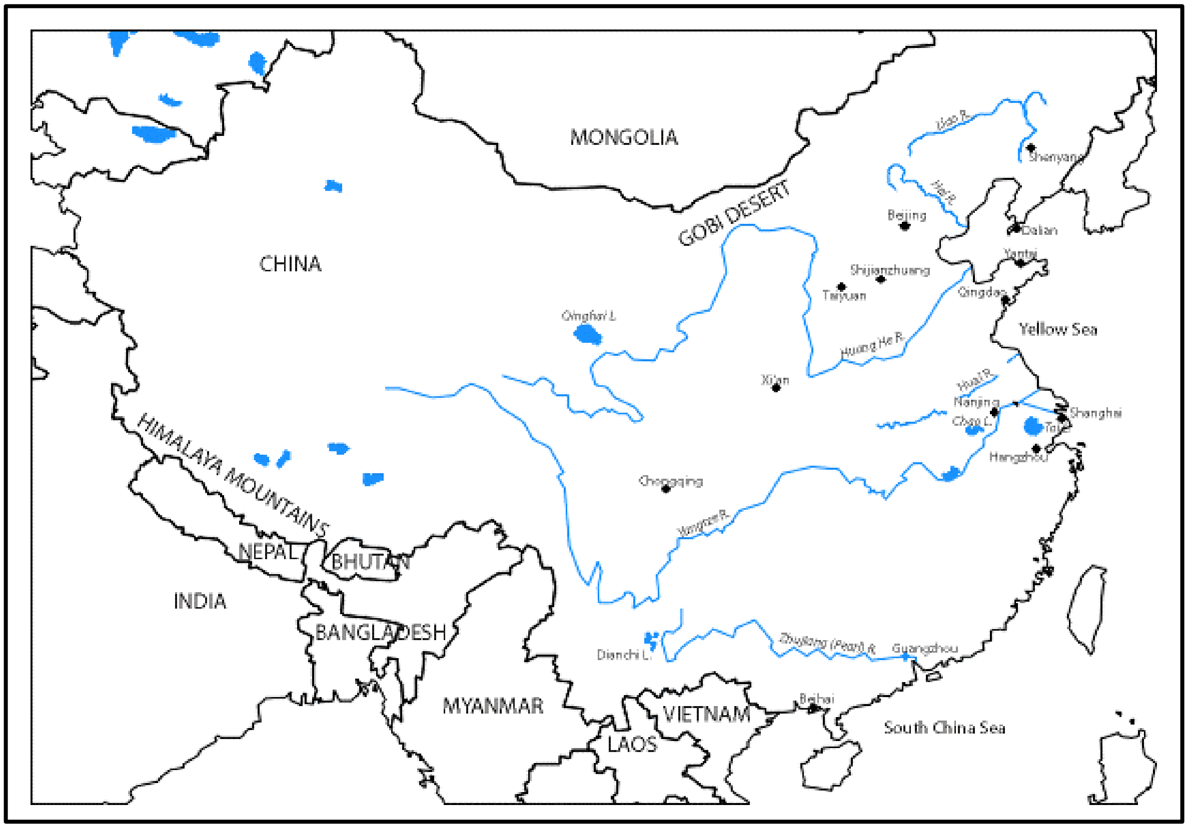
The three main environmental problems that were investigated in this study are health effects due to air pollution, drinking water contamination, and industrial pollution from town / village enterprises (TVE) with additional topics on lead pollution among children and other chemical pollution.

In particular, the project collected and analyzed disaggregated data to identify which segments of the population, and in which areas, are suffering from environmental pollution. These can be linked to poverty and sustainable development in China.

Background

China is the largest of all Asian countries and has the largest population in the world. Occupying nearly the entire East Asian landmass, it stretches for about 5,000 kilometers from east to west and 5,500 kilometers from north to south and covers an area of about 9,572,900 square kilometers, which is approximately one-fourteenth of the land area of the Earth.

China has 33 administrative units directly under the Central Government; these consist of 22 provinces, 5 autonomous regions, 4 municipalities (Beijing, Shanghai, Tianjin, Chongqing), and Hong Kong and Macau Special Administrative Regions. According to the topography, China has seven major regions, such as North, Northeast, East, Central, Northwest, Southwest and South. The climate in the southeast regions of the Yangtze River is subtropical to tropical compared to those in the northwest part. Average temperatures in January range from 0° C at the divide to 22° C along the southern coast of Hainan Island, and decreases northward from the divide, ranging between -1°C and -30°C throughout the Manchurian and North China plains.



The population is also quite unevenly distributed, with the great majority living in the easternmost third of the country. The most densely populated areas are the alluvial plains on which both intensive agriculture and urban growth are prominent. The extensive western regions are sparsely populated, with large areas of desert and mountainous terrain that are virtually uninhabited.

Despite rapid industrialization and urbanization, most Chinese still live in villages in the countryside. More than one-fourth of the total population is found in urban areas. After encouraging economic development beginning with the 1980s, China gained one of the highest economic growth rates in the world. However, the economic development is unbalanced between east and west, south and north. The gross national product per capita remains relatively low in the north and western areas of China.

Responsible agency for environmental health in China

At the national level, the Ministry of Health (MOH) is responsible for environmental health in China. Special management and technical teams have been established throughout the country for the inspection and assessment of health effects of environment pollution. This system has been in operation for the last several decades. At the provincial or county level, there are available Sanitation and Anti-epidemic Stations, which perform functions related to environmental health. Some progressive cities have specialized agencies with separate centers for disease prevention and control as well as public health inspection and supervision, which include surveillance.

The Institute of Environmental Health and Engineering, the research and teaching arm of the Chinese Academy of Preventive Medicine, is part of the MOH. However, it does not have any policy or regulatory function. The CAPM is undergoing reorganization in the next few years, which will possibly include a more specific role for environmental health.

Environmental monitoring sites and disease surveillance points

In China, the monitoring of ambient air quality is undertaken in almost half of the 668 cities. The Chinese Disease Surveillance Points (DSP) was established in 1990 at about 145 sites representing a population of about 10 million. However, only 28 cities have both air quality monitoring sites and disease surveillance points as listed in Table 1.1. To determine proper correlation between ill health and environmental pollution and as an input to planning and decision-making, it would be prudent to increase these common sites and establish environmental monitoring stations close to the DSP points.

Rural and urban mortality profile

From the Chinese Disease Surveillance Points, disaggregated mortality data were analyzed for both rural and urban settings from 1991-98 using older people between 60-84 years old since they are usually more sensitive to changes in environmental and other factors. To observe the urban-rural difference, the ratio of urban mortality rate to rural mortality rate (MRR) for each sex, cause and year was computed. The mortality rate in cities has been decreasing, whereas the mortality rate in rural area has been increasing.

It is reasonable that cancer (neoplasm) mortality rate is higher in cities than in rural areas because outdoor air pollution level is usually higher in cities than in rural areas. On the other hand, mortality rate from other diseases is lower in cities. This may be due to better access to medical facilities in cities, or other socio-economic differences between urban and rural areas.

One possible explanation of the downward trend of cancer mortality ratio is that the increased mortality trend in rural area was somewhat affected by pollution from town and village enterprises (TVE), which began to pollute rural areas in 1970s. Hence this would raise mortality rate from neoplasm only after about 20 years of exposure.

Air pollution and health

Coal usage accounts for 78% of China's energy supply since it is the cheapest and most convenient to use. There are different types of coal in China but most coal reserves have medium ash content (10-20%) and low to medium sulfur content (0.5 - 4%), mostly used by industries. This somehow complicates environmental and health protection as coal combustion continues to be the major source of air pollution in the whole country. Almost all cities in China exceeded the country's ambient standards for total suspended particulates (TSP), nitrogen oxide (NO_x) and sulfur dioxide (SO_2).

Motor vehicle emissions from unleaded fuel in cities had been a significant source of urban air pollution. Beijing is currently using unleaded fuel. The Chinese standards for concentrations of hydrocarbon, carbon monoxide, and ozone are all exceeded in major cities with large fleet of motor vehicles such as automobiles.

Indoor air pollution is due to the use of smoky coal for both cooking and heating especially in cold regions. Residents especially females and children are exposed to very high levels of particulates as well as carcinogenic polyaromatic hydrocarbons. The particulates from smoky coal burning are less than 10 microns (PM10) that tend to remain longer in air, easily inhalable and can be effectively deposited in the lungs.

Throughout the country, especially in heavily polluted regions, the major diseases caused by air pollution were identified to be chronic obstructive pulmonary diseases (COPD), lung cancer, and lead poisoning. There were numerous literatures in both Chinese and English, which provided correlation between air pollution and lung cancer. However, as most Chinese males are smokers, this can be a confounder when evaluating the actual risk factors. According to a recent three-year national survey of 28 selected cities in China, more than half of the Chinese urban children have blood lead levels higher than the WHO guideline of 100 microgram per liter. Elevated blood lead levels of 109-330 microgram per liter can cause learning impairment and behavioral abnormality.

Water pollution and health

There is a large concern over widespread pollution of rivers, lakes, groundwater, and coastal waters in China due to rapid population and urban growth, agricultural runoff with pesticides and fertilizers, and untreated industrial discharges. The water quality of the seven major rivers, especially Yangtze and Yellow Rivers, is reported to be deteriorating. Even the so-called "Three Lakes" such as Taihu Lake, Dianchi Lake, and Chaohu Lake are highly eutrophied and laden with algae and cyanobacteria producing toxins such as microcystins. Microcystins in drinking water cannot be completely removed by common disinfection nor heating.

The effects of water pollution on health have been documented in the last two decades in China. There is significant evidence showing correlation between drinking water contamination and liver cancer prevalence as was reported in Jiangsu province in the early

1980s. Endemic fluorosis such as dental and skeletal fluorosis has affected more than 24 million people in 1999. This is due to regular ingestion of drinking water with high levels of fluoride as high as 5 mg/L (WHO guideline is 1 mg/L) in the northeast and central part of the country. Endemic arsenism is a serious problem mainly in Xinjiang, Inner Mongolia, Shanxi, and Guizhou where more than 15 million people had ingested drinking water from groundwater wells with arsenic concentration between 0.03 – 0.65 mg/L (WHO guideline is 0.01 mg/L). Cases of skin cancer and malignant neoplasms found as early as 1988 were correlated with high arsenic concentration in drinking water.

TVEs and health

Town and village enterprises (TVEs) and other private sectors are playing a larger role in the economic development of China. TVEs are various enterprises established outside of urban areas with the majority of investment from rural collective organizations or farmers. There are around 7 million TVEs, which account for more than 60% of the total industrial GDP. According to the China Environment Yearbook, TVEs discharge about 50% of the industrial wastewater and air pollutants. Most TVEs have no wastewater or hazardous waste treatment facilities. Although there is scarce information on the health effects due to TVEs, it is predicted that they could become a major risk factor especially in rural areas. The government has been somewhat protective of TVEs and lenient in their environmental controls since they contribute most to the country's export earnings. However, this is expected to change in the future due to better environmental policies and stricter implementation.

Health risk index for China

The health risk index for all the provinces in China was developed. The detailed methodology with sample calculations is described in Chapter 3. The health risk index (HRI) is inversely proportional to the human development index (HDI) developed by UNDP. The HRI was developed based on the principles and approaches used by UNDP and WRI but adapted to the situation in China. For the 27 provinces and 3 autonomous cities of China (excluding Chongqing), four indicators to estimate the likely health risk potential were considered - exposure to polluted indoor and outdoor air, exposure to polluted drinking water, poor nutrition and access to health services. The fourth one, though not due to environmental conditions, can influence the total risk potential in terms of being able to provide timely medical attention. The indicators and the variables used to calculate the HRI are:

a) Air pollution:
    - Indoor air pollution - Residential coal consumption, tons per household
    - Outdoor air pollution – percentage of population living in cities exceeding WHO guidelines

b) Water pollution: percentage of population without access to safe water

c) Poor nutrition: percentage of under-5 children who are underweight

d) Access to health services: percentage of population without access to health services.

As in other developing countries, there is scarcity of data in China for both environment and health statistics. In many cases, proxy indicators for human-environment relationships were applied as well as the best available database such as published yearbooks between 1995-1999. Some data used may be of low quality or incomplete.

Linear transformation of the derived formula was applied to each of the calculated values to obtain the respective index value. All the indicators were assigned equal weights and the HRI was computed by getting the average of the four indices. A detailed description of this method is in Chapter 3.

The results showed the top three provinces with highest HRI to be (1) Tibet, (2) Ningxia, and (3) Guizhou, i.e., they have higher health risks. The last three slots are (28) Jiangsu, (29) Beijing, and (30) Shanghai, i.e., they have the least health risks.

1.2 Overview of the linkage between health, environment and socio-economic cost

The human environment consists of basic features such as the air (we breathe), the water (we drink), the food (we eat), the weather (affecting our lifestyle), and the place we live and work. When a person gets sick, the disease is caused by environmental factors or by genetic factors, most especially relating to age. The relative contribution of the different factors to the overall mortality and morbidity in a community are difficult to measure since the major diseases are multifactorial. But it is important to understand why and how diseases occur to be able to prevent them or reduce the exposure. Environmental pollution is very costly to eliminate but it has to be done especially when it affects people's health. Environmental health authorities should find an acceptable balance between health risks and the economic costs of prevention.

Common sites for both air quality and disease surveillance in China

Of the 145 DSP sites throughout the country, only 28 have environmental monitoring data. These common sites are listed in Table 1.1. Disease data and air quality data for these sites were used to determine the correlation between air pollution and respiratory diseases and cancer.

The Department of Disease Control of MOH has established the National Disease Surveillance Point System (DSP) at 145 sites in 31 provinces since 1990. It covers almost the whole country and approximately 10 million populations, with at least 30,000 for each site. Since the DSP data were based on self-reports from hospitals, it is possible that there were some biases and modifying factors, but the results were checked carefully and adjusted using Model Life Table. To analyze the association between air pollution and health effects, the relative mortality data from the DSP report during 1991 to 1998 were collected. The definition of disease according to the International Classification of Disease (ICD) is shown in Table 1.2. ICD-9 was used although ICD-10 is already in place.

Table 1.1 List of 28 common sites for both environmental monitoring and disease surveillance in China

Monitoring Sites	DSP Sites	Monitoring Sites	DSP Sites
Zhengzhou	Zhengzhou City	Lasa	Lasha City / Chengguan
Yinchuan	Yinchuan City	Lanzhou	Lanzhou City / Chengguan
Xining	Xining City / Chengzhong	Kunming	Kunming City / Panlong
Xi'an	Xi'an City / Beiling	Huhehaote	Hu City / Huiming
Wulumuqi	Wulumuqi City / Tianshan	Hefei	Hefei City / Zhongshi
Wuhan	Wuhan City / Jiang'an	Hangzhou	Hangzhou City / Xiancheng
Tianjin	Heping	Haikou	Haikou City / Bo'ai
Taiyuan	Taiyuan City / Beicheng	Ha'erbin	Ha'erbing City / Nangang
Shijiazhuang	Shijiazhuang City / Chang'an	Guiyang	Guiyang City / Nanming
Shanghai	Luwan	Guangzhou	Guangzhou City / Yuexiu
Nanning	Nanning City	Fuzhou	Fuzhou City / Changshan
Nanjing	Nanjing City / Xuanwu	Chengdu	Chengdu City / Qingyang
Nanchang	Nanchang City / Donghu	Changsha	Changsha City / East
Beijing	Dongcheng	Changchun	Changchun City / Nanguan

Data were analyzed using SAS 6.12 (SAS, Institute, Inc). To improve the normality of the data distribution, log-transformed concentration of air pollutants and the mortalities for significance test, correlation analysis, and GLM analysis (General Linear Model) were applied. While doing analysis, the mortality was disaggregated into 4 age groups, including 0~14, 15~39, 40~59 and 60~84 age groups, summing up the data from 1991 to 1998. In the GLM procedure, to control other factors associated to region, such as environment, climate, income, custom, etc, the 7 regions were used as subvariables to adjust the results. The uncertainties in the effect estimates were quantified and the results were given as a range (95% CI of the exposure-response function).

Air quality monitoring data

Chinese SEPA has established an air quality monitoring system in more than 300 urban cities since the 1980s. There are four or more monitoring sites in each city. The Chinese air quality standards are shown in Table 1.3. The annual concentration of TSP, SO_2, and NOx in the 28 major cities from 1991 to 1998 were obtained from the Chinese SEPA Environment Yearbook and correlated with short and long exposure to air pollution. The ranges of annual average concentration are 83-615 μg/m^3 for TSP, 2-349 μg/m^3 for SO_2, and 16-125 μg/m^3 for N0x.

Table 1.2 Definition of disease according to ICD-9

Types of Diseases	ICD-9	Description
Neoplasm	08-17	Including lung cancer, liver cancer, esophagus cancer, stomach cancer and other cancers.
Lung cancer	11	Malignant neoplasm of trachea, bronchus and lung.
Cardiovascular diseases	25-30	Including rheumatic diseases, hypertensive disease, ischemic heart disease, pulmonary circulation and other forms of heart diseases, chronic pulmonary heart diseases and cerebrovascular diseases.
Ischemic heart disease	27	
Pulmonary heart disease	28	Disease of pulmonary circulation and other forms of heart disease
Chronic pulmonary heart disease	282	
Respiratory disease	31-32	Including the diseases of upper respiratory tract and other diseases of respiratory system, such as COPD
Chronic obstructive pulmonary disease (COPD)	323	Including bronchitis, chronic bronchitis, emphysema and asthma

Major results of health risk analyses on air pollution in the 28 DSP cities

According to the monitoring data for air quality in major cities in China from 1991 to 1998, the air pollution has decreased gradually during this period. Recently, NOx pollution in some cities has increased which may be attributed mainly to an increase of motor vehicles. Coal burning is the main source of pollutants. SO_2 and TSP concentrations are two to three times higher than Grade II National Standards for Air Quality especially in the northern and western part of the country due to large consumption of high-sulphur coal.

The four leading causes of death in Chinese population are cardiovascular diseases, chronic respiratory diseases, neoplasm and accidents, although their mortality rates vary according to sex and region (urban and rural). These variations may be due to several factors but due in most part to environmental pollution.

Table 1.3 Chinese ambient air quality standards and that of World Health Organization (micrograms per cubic meter)

Pollutant	Averaging Time	China			World Health Organization
		Class 1	Class 2	Class 3	
Sulfur dioxide	Annual	20	60	100	40-60
Total suspended particulates	Daily	150	300	500	150-230[b]
	Annual[a]	60	120	150	60-90
PM-10	Daily	75	150	250	70
	Annual[a]	20	60	100	
Carbon monoxide	Daily	4	4	6	10[c]
Nitrogen oxides	Daily	50	100	150	150
Ozone	8 hours				100-120
Lead	Annual	0.7			0.5-1.0

Note: Class 1 are tourist, historic, and conservation areas. Class 2 are residential urban and rural areas. Class 3 are industrial areas and heavy traffic areas.

a. Since China does not have annual standards for total suspended particulates, it has been assumed that the same ratio between daily and annual standards for sulfur dioxide applies to total suspended particulates. Annual standards are needed for comparability with ambient concentration data.
b. Guideline values for combined exposure to sulfur dioxide and total suspended particulates.
c. 8 hours.

Source: WHO and UNEP 1992; World Bank staff estimates.

Between 1991-98, it was found that the mean annual mortality rates of respiratory diseases, cardiovascular diseases, lung cancer and neoplasm in the 28 DSP cities were higher in heavily polluted cities with TSP and SO_2 compared to less polluted ones, especially among older people of 60-84 years. However, covariate analyses using the GLM (General Linear Model) Procedure showed significant correlation only with SO_2 but not with TSP or NOx almost consistently for all ages. The log-log relationships in terms of regression line between SO_2 concentration and mortality rates of respiratory diseases for all ages, cardiovascular diseases for ages of 60-84 years and lung cancer for all ages, with adjustment, are presented in Table 1.4.

According to these regression lines, the excess death from respiratory diseases for all ages, cardiovascular diseases for ages of 60-84 years and lung cancer attributed to outdoor air pollution exceeding the grade II National Standards for Air Quality were estimated to be 127,000 (SE - standard error): 5,800), 205,000 (SE:8,100) and 44,000 (SE:2,100), respectively, totaling 376,000, in all urban areas in the provinces where the 28 DSP cities are located.

Table 1.4 Excess death from three diseases in 28 DSP cities attributable to outdoor air pollution (SO_2)

Diseases	Regression Lines	Excess Deaths
Respiratory diseases for all ages	log(annual mortality rate of respiratory diseases) = 0.3033 log(SO_2) + 0.964	127,000 (SE: 5,800)
Cardiovascular diseases for ages 60-84	log(annual mortality rate of cardiovascular diseases) = 1.991 log(SO_2) + 2.7426	205,000 (SE: 8,100)
Lung cancer for all ages	log (annual mortality rate of lung cancer) = 0.5722 log(SO_2) + 0.3149	44,000 (SE: 2,100)
Total		**376,000**

Ecological correlation between air pollution and mortality risks

The mean annual mortality rates (log-transformed) of respiratory diseases for all ages and aged (60-84 years) people, cardiovascular diseases for aged group and all cancers for all ages and aged people for the 28 DSP sites showed significant ecological correlations especially with outdoor SO_2 concentration but not with TSP or NOx in terms of means (log-transformed) for the same period. This unexpected association between SO_2, which is not a carcinogenic pollutant, and lung cancer indicates that SO_2 concentration is only a representative index of a more complex pollution situation.

There is no data on fine particulate matters such as PM10 or PM2.5, which may include carcinogenic substances. In the TSP analysis, large particles of soil or sand are included and may not contain carcinogenic substances such as from coal burning. Hence the findings did not establish strong correlation with TSP but rather with SO_2. However, better correlation with TSP was found when the subject area is restricted to a small one as in some epidemiological studies in Shenyang or Taiyuan, where TSP components are expected to be more or less homogeneous.

The data on coal consumption per household in each of the provinces has also been shown to correlate significantly with the mortality rates of the three diseases, indicative of the health risks of indoor pollution due to cooking and heating purposes.

Urban and rural mortality profile

Figure 1.1 shows the trend of mortality rates for selected causes of death. The curve of neoplasm (cancer) shows a downward trend, although the ratio is still higher than 1.0 even in 1998. With only one exception, the ratios for the other diseases are less than 1.0, indicating higher mortality rates in rural areas than in urban areas. Respiratory diseases show downward trend, whereas other diseases have no particular trend. Figure 1.2 shows the pattern among females. The overall trend is similar to that in Figure 1.1, indicating that there is no substantial difference in the trend between males and females. Absolute mortality rates from neoplasm for cities and rural areas are shown in Figure 1.3. The mortality rate in cities has been decreasing, whereas the mortality rate in rural area has been increasing.

It is logical that cancer (neoplasm) mortality rate is higher in cities than in rural areas because outdoor air pollution level is usually higher in cities than in rural areas. On the other hand, mortality rate from other diseases is lower in cities. This may be due to better access to medical facilities in cities, or other socio-economic differences between urban and rural areas.

One possible explanation of the downward trend of cancer mortality ratio is that the increased mortality trend in rural area was somewhat affected by pollution from town and village enterprises (TVE). Figure 1.3 reinforces this speculation in that the TVE began to pollute rural areas in 1970s, which would raise mortality rate from neoplasm after about 20 years of exposure.

Figure 1.1 - Trend of urban to rural ratio of major specific mortality rates, 60 – 84 years of age

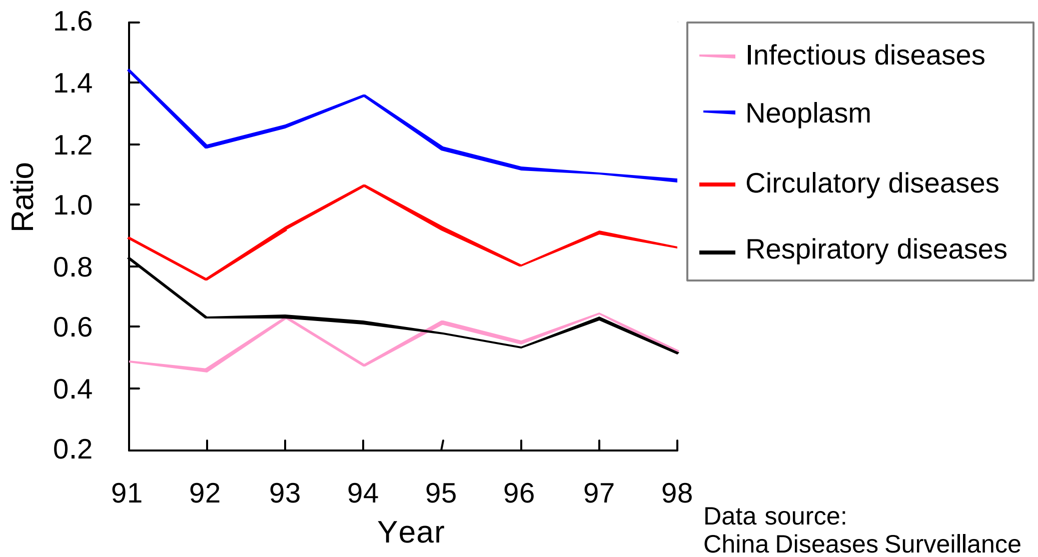


Figure 1.2 – Trend of urban to rural ratio of major cause-specific mortality rates in females 60-84 years of age

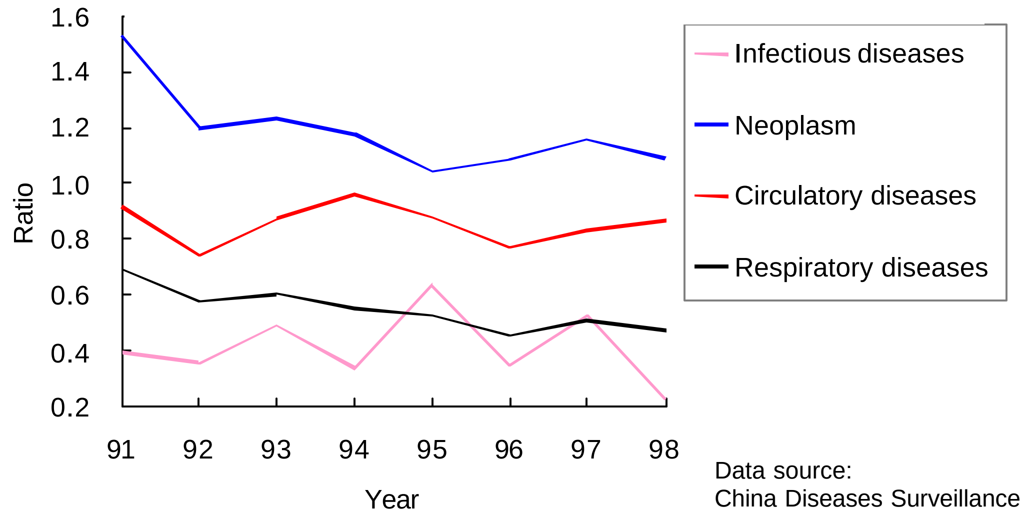
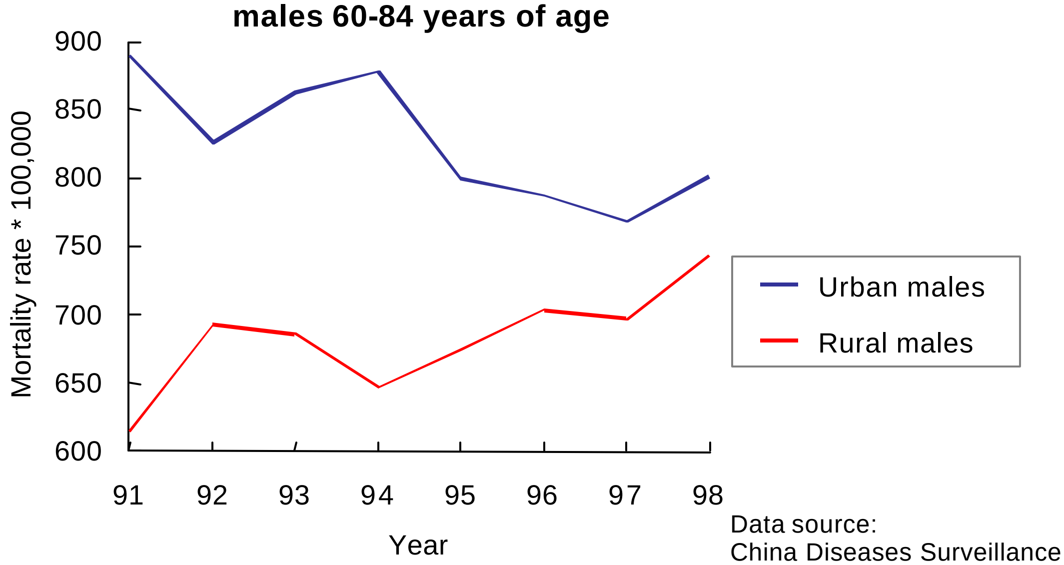


Figure 1.3 - Trend of neoplasm mortality rate in males 60-84 years of age



Relevant studies on economic valuation of health impacts due to environmental pollution

In this report, only the economic loss of health impacts due to outdoor air pollution was estimated using the willingness to pay and human capital approach. There is insufficient data to use for estimating economic losses due to water pollution and TVEs. The exposure-response relationship established in China was used as much as possible.

In China, there have been at least 10 estimates of economic losses caused by TSP and SO_2 since 1990 at the national level (first level). Based on Table 1.5, the institutes and researchers involved in these studies were:

1. The Environmental Science Research Institute of China, Guo Xiaomin, Zhang Huiqin (1990);
2. The Environment and Development Research Center of Chinese Academy of Social Sciences (CED,CASS) Zheng Yisheng, et al. (1995, 1997, 1998);
3. The Policy Research Center of the National Environmental Protection Bureau, Xia Guang, Sun Binyan, et al. (1995, 1997);
4. The World Bank (1994, 1997);
5. The East-West Center, Honolulu, USA, V. Smil (1996);
6. The Institute of Environmental Health and Engineering of the Chinese Academy of Preventive Medicine, Xu Fang et al.(1992)

There have been at least 20 environmental cost estimates at the provincial level or in large cities (second level), which include health impact and its associated cost. The third level studies of the health effects of pollution are the surveys in selected special industrial zones. These surveys were mainly related to specific pollutants, such as, lead, fluorine, and arsenic, among others. Few of these studies have valued the damage to health. The parameters TSP and SO_2 were alternately taken as health affecting indicators to determine the exposed population. Economists have difficulty in distinguishing whether SO_2, TSP or other pollutants are responsible for health effects. Apparently, the association between air pollution and disease is not easy to establish.

Recent estimates (2001) of excess mortality and morbidity (with SO_2 as indicator) show that by calculating cost of illness through human capital approach, the economic cost of health impact due to air pollution is 43.8 billion RMB yuan, which is bigger than another estimation (with TSP as indicator) of 19.1 billion RMB yuan (1998 price).

Using the willingness to pay approach (WTP), the annual economic loss of excess mortality due to outdoor air pollution (exceeding the Class II air quality Standard for SO_2) is about 85.5 ~ 159.3 billion RMB yuan (1998 price), which accounts for 1.1 ~ 2.0% of GDP. On the other hand, when using the human capital approach, the economic loss of excess mortality and morbidity is 43.8 billion RMB yuan, which accounts for 0.6% of GDP. The estimation by human capital approach, however, has seriously underestimated the real cost of air pollution due to the limitation of methodology although this is popularly used in China.

Table 1.5 Related studies on excess mortality due to outdoor air pollution in China

Institution	Affected Population (million)		Dose-response (mortality)	Excess Death
NEPA (1990)	81.9	Cities exceeded national 2nd class standard (SO_2)	8.33/100,000 difference between polluted area and clean area (lung cancer)	68,000
Xia Guang (1995)	162.0	Cities exceeded national standard (TSP,0.3mg/ m^3)	Same as above	13,000
CED, CASS (1998)	180.0	50 million people (above 0.5mg/m^3,TSP)	10 percent increase in total mortality for every 0.1mg/ m^3 increase of TSP	160,000
World Bank (1997)	240.0	80 percent of urban population exposed to levels in Beijing in 1995 (TSP and SO_2)	Number of additional deaths per 1 million people for every 0.001mg/ m^3 increase PM10	178,000
Smil (1996)	250.0	Exposed to level 0.3-0.5mg/ m^3 (TSP)	An estimation; calculation procedure is not clear	130,000
IEHE-CAPM, WHO-UNDP* (2001)	28 DSP sites	Cities exceeding SO_2 standards	Log (A1*)= 0.3033 1og (SO_2) + 0.964	127,000
			Log (A2)= 1.991 log (SO_2) + 2.7426	205,000
			Log (A3)= 0.5722 log (SO_2) + 0.3149	44,000
			Sub-total for IEHE / WHO:	376,000

*A1: annual mortality rate of respiratory diseases;
A2: annual mortality rate of cardiovascular diseases;
A3: annual mortality rate of lung cancer

Medical expenditure for excess mortality

The average medical expenditure in a hospital for each patient who died of respiratory disease is 11,500 RMB yuan (in 1998 prices) which includes outpatient service 3,500 yuan, hospitalization expenses 7,500 yuan, and the payment for health care workers 500 yuan. In addition, average indirect cost for each urban inpatient is 670 yuan and the medical expenditure that is not through hospital, i.e., buying medicine from grocery/drug stores, is about 1,100 yuan. It is a conservative estimate since in urban areas, about half of patients go directly to grocery stores and not to hospitals.

Thus, the comprehensive medical expenditure for a patient who died of respiratory disease is 13,270 RMB yuan (1998 price). Table 1.6 provides a summary. This is expected to rise in the next few years based on past trends. For example, the expenses in outpatient service have increased by 44% each year during 1993-1998. Using total excess death of 376,000 in the 28 DSP sites, the medical expenditure for excess mortality is 8.33 billion RMB yuan.

Table 1.6 Medical expenditure for each cause of excess death

Cause of death	Excess Death	Medical Expenses Per Capita (RMB yuan)
Respiratory disease	127,000	13,270
Lung cancer	44,000	89,270
Cardiovascular disease	205,000	13,270

Estimates of economic losses due to air pollution

Using total excess death of 376,000 in the 28 DSP sites, the medical expenses for excess mortality is 8.33 billion RMB yuan. The economic loss of decrease of working days is 6.34 billion RMB yuan. The total "value of life" loss due to excess death is 23.88 billion. Estimate of medical expenditure for morbidity due to COPD is 5.2 billion RMB yuan. By cost of illness and human capital approach, the estimate of economic losses of excess mortality and morbidity is 43.8 billion RMB yuan (1998 price) for the 28 DSP sites (Table 1.7).

Table 1.7 Estimated costs of health impacts due to air pollution

Attributable Expenses	Estimated Cost (billion RMB yuan)
Medical expenses due to excess mortality	8.33
Loss of working days	6.34
"Value of life" loss	23.88
Medical expenses due to excess morbidity(COPD)	5.2
Total	43.8

Chapter 2
Detailed Description of Health Impacts of Pollution in China

2.2 Air pollution and health

Air pollution indicators in relation to health risk analyses

Data on air pollutants and some indices listed below are based on available statistics and published yearbooks. Data for the 28 DSP sites were obtained from 1991 to 1999. These 28 major cities from DSP sites covered almost the whole country in 20 provinces, 5 autonomous regions and 3 municipality cities, excluding Liaoning province, Shangdong province and Chongqing City.

a) *TSP, SO_2 and NOx*: annual concentration of air pollutants in each major city from 1991 to 99. This should be an index of outdoor air pollution in urban areas.

b) *industrial coal consumption*: annual amount of coal consumed by industry at the provincial, autonomous region and municipal city level. This should be related to outdoor air pollution in urban areas.

c) *residential coal consumption*: annual amount of coal consumed by residents at the provincial, autonomous region and municipal city level. This should also be related to outdoor air pollution in urban areas.

d) *residential coal consumption per household*: average annual amount of coal consumed by residents at the provincial, autonomous region and municipal city level per household. This index may be related to the average indoor air pollution due to coal use for cooking and heating in each household whether urban or rural area.

e) *total number of cars*: annual number of cars at provincial, autonomous region and municipal city level. This should be related to the outdoor air pollution, especially NOx pollution.

f) *waste gas emission*: annual amount of waste gas emission from industries at provincial, autonomous region and municipal city level. It contains air pollution from TVEs without treatment.

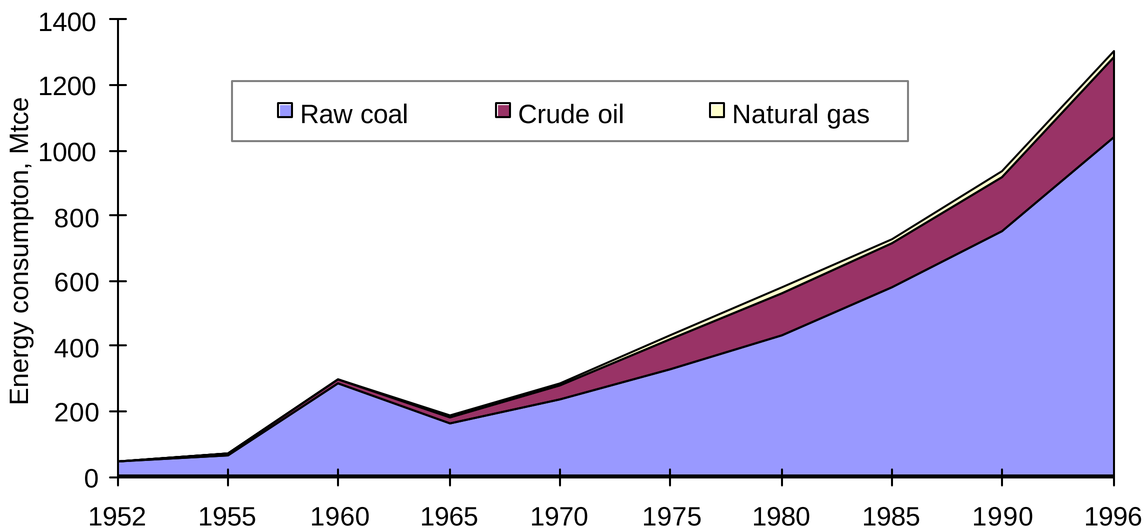
Sources of air pollution

The main sources of air pollution in China in both rural and urban areas are emissions from coal burning, motor vehicles, and industries.

Coal

Coal combustion is still a major source of both outdoor and indoor air pollution from industrial and domestic uses such as cooking and heating especially in traditional houses still prevalent in most part of the country. China is the largest coal producer and consumer in the world. The reserve of coal is about 860 billion tons. In 1996, China produced a total of 1.4 billion tons of raw coal. Coal accounts for more than 75 % of China's total consumption of primary energy (Figure 2.1), compared with 17 % in Japan and a world average of 27 %. Coal forms around 78% of electric power output, 60% of commercial energy for household use and 70% of chemical raw materials. Such high reliance on coal will not change in the next decades. Meanwhile, coal burning is the primary source of China's high SO_2 and TSP emissions. In 1994, coal burning produced 90% of total dust emission, SO_2 emission and CO_2 emission of the whole country (IEA, 1997).

Figure 2.1 - Trend of energy consumption in China



There are several kinds of coal, such as blind coal, soft coal, and coking plant soft coal. However, the quality of coal in China is poor, especially the southwestern part. Coal has about 25% ash with an average value of 17.6%. Coal with high sulphur is mainly distributed in the southwest part of China, such as Sichuan, Chongqing and Guizhou, with maximum sulphur content of about 6.26%, 4% and 4.6%, respectively.

In 1998, the industrial and residential coal consumption per km^2 in northern China was largest among the seven regions (Figures 2.2 and 2.3). However, the region with highest residential coal consumption per household has been the southwest part (Figure 2.4). Industries account for two-thirds of total coal use; industrial boilers alone consume 30 percent. These boilers are usually inefficient and emit fine particulates and SO_2 through low smoke stacks. Industries with dirty boilers are located in densely populated metropolitan areas, placing communities in these areas at high risk of exposure.

Figure 2.2 - Comparison of industial coal consumption per km^2 among regions

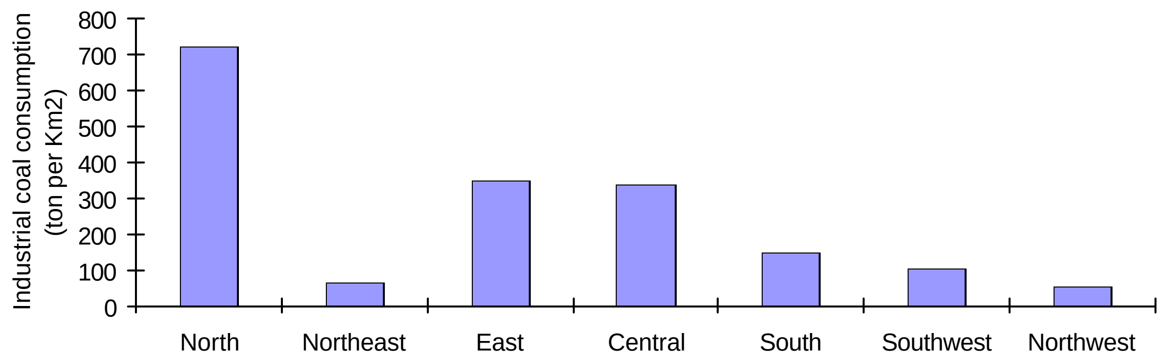


Figure 2.3 - Comparison of residential coal consumption per km^2 among regions

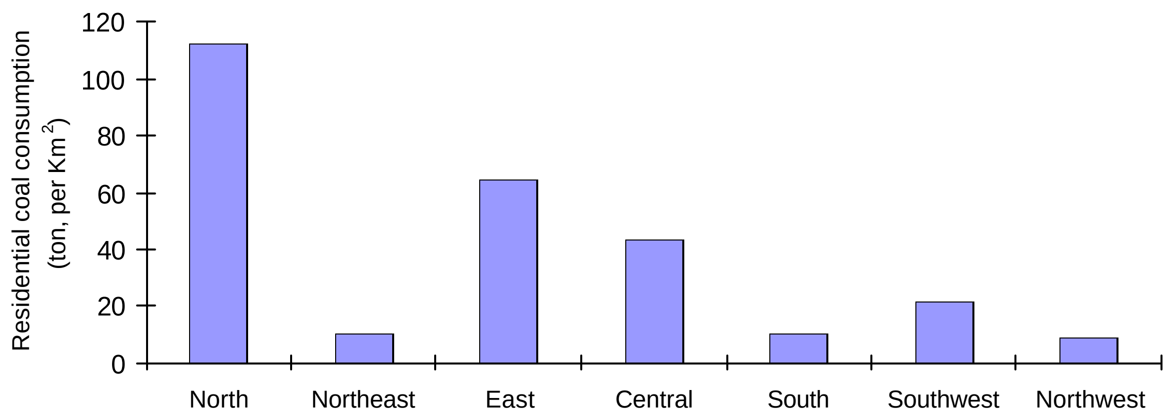
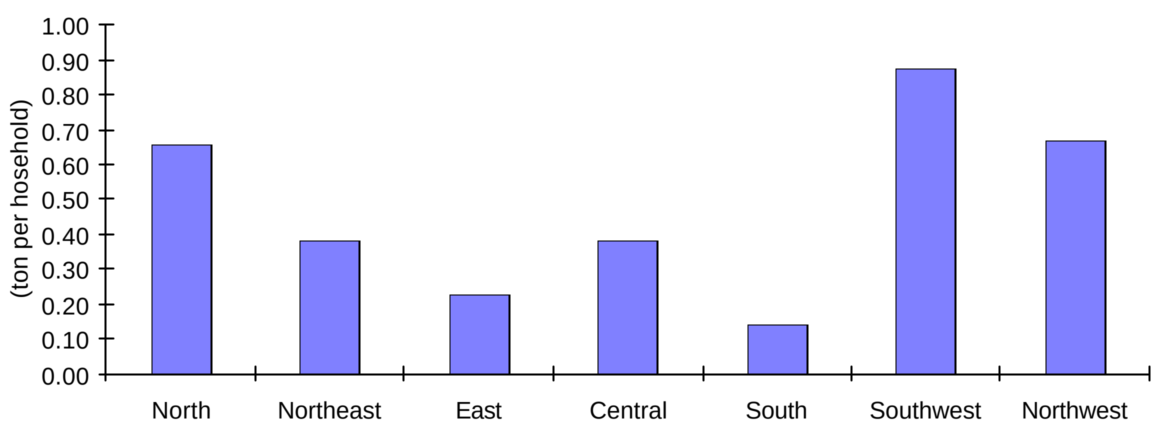


Figure 2.4 - Residential coal consumption per household by region



Motor Vehicles

The energy and industrial sectors are now the biggest contributors to urban air pollution in China. However, the transportation sector is becoming increasingly important. The number of motor vehicles has tripled since 1984, rising from less than 2.4 million in 1984 to 9.4 million in 1994. By 2020, the number of urban vehicles is expected to be 13 to 22 times greater than it is today (Stares and Liu, 1996). This trend will likely have a major influence on the future of China's air quality. The shift toward vehicle use is most apparent in China's big cities. For example, from 1986 to 1996, the number of vehicles in Beijing increased fourfold, from 260,000 to 1.1 million.

The problem stems not just from the growing size of the vehicle fleet but also from low emissions standards, poor road infrastructure, and outdated technology, which combine to make Chinese vehicles among the most polluting in the world (Walsh, 1996). According to the monitoring data on traffic pollution in Beijing as shown in Table 2.1, all parameters exceeded the national standards at road intersections.

Table 2.1 Average levels of major air pollutants in Beijing crossroads with traffic congestion

	CO (mg/m^3)	**SO_2** (mg/m^3)	**NO_2** (mg/m^3)	**HC** (mg/m^3)	**BaP** (μ g/m^3)	**Pb** (μg/m^3)
Average daily concentration	52.8	1.35	4.40	1.00	6.3	23.0
National standard for air quality	4.00	0.15	0.08	--	0.01	1.00 (annual)

Waste gas emission from industries

According to this data, the industrial waste gas emissions of China reached 1.1 billion tons in 1998. Many small-scale industries and TVEs have no pollution control and they contribute significantly to industrial pollution. However, as shown in Table 2.2, the emission of waste gas decreased in recent years due to stricter regulations.

Ranges of air pollution and several indices among major cities

Table 2.3 lists the ranges of mean annual average concentrations of TSP, SO_2, NOx, and several related indices among the 28 DSP sites.

Table 2.2 Waste gas emission in China from 1991 to 1998, million tons

	1990	1992	1993	1994	1995	1996	1997	1998
Waste gas	850	1050	1100	1140	-	-	1130	1100
SO_2	1495	1685	1795	1795	-	-	2346	2090
Ash	1324	1414	1416	1414	-	-	1873	1452
Dust	781	576	617	583	-	-	1505	1322
TSP in north cities	475	403	407	407	392	387	381	-
TSP in south cities	268	243	251	250	242	230	200	-

Table 2.3 Ranges of air pollution and several indices among 28 cities

Pollutants or index	Minimum	Maximum
TSP (µg/m^3)	83	616
SO_2 (µg/m^3)	2	349
NOx (µg/m^3)	16	125
Industrial coal consumption (10,000 ton)	138	6071
Residential coal consumption (10,000 ton)	0.22	1131
Residential coal consumption per Km^2 (ton/km^2)	0.06	280
Residential coal consumption per household (ton/household)	0	1.7
Total car (number)	38044	1355074
Waste gas emission (million tons)	11	7698

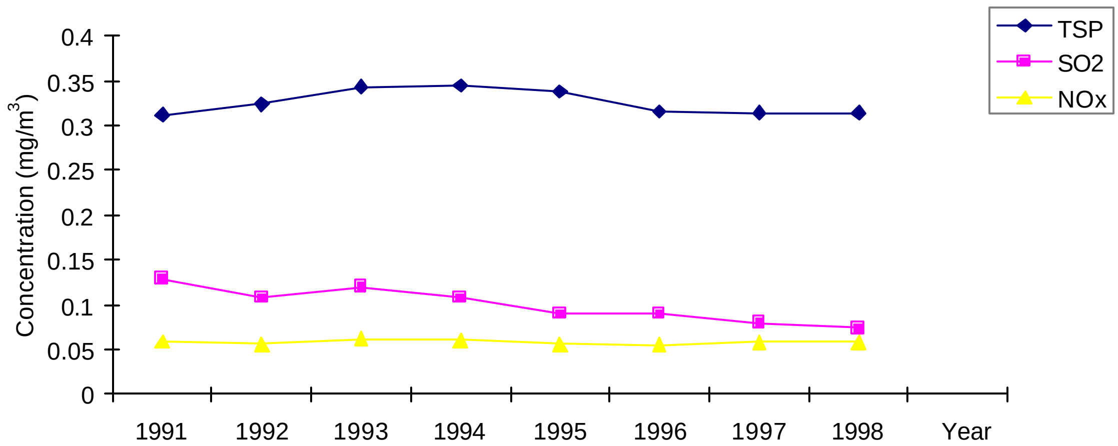
State of air pollution in China

China has long recognized air pollution as a serious problem. Ambient concentration of TSP and SO_2 in urban areas are among the world's highest. According to the environmental monitoring data from the China Environment Yearbook for urban air quality in major cities of China, the TSP pollution was severe in the 1990s. Its average annual concentration was stable at 300µg/m^3 from 1991 to 1998. Meanwhile the SO_2 concentration decreased from 129µg/m^3 in 1991 to 69µg/m^3 in 1999 with the NOx concentration almost constant at 60µg/m^3 (Figure 2.5).

Geographical variation in air quality

Only cities like Haikou, Xiamen and Beihai are meeting the air quality standards while all other cities exceed the WHO standards. Based on the environmental monitoring results from 322 cities of China in 1998, only 89 cities or 27.6% meet the Class II national standard for air quality. Moreover, the extent and type of air pollution in China varies considerably by geographic region. TSP and NOx concentrations were higher in north than in south cities, while SO_2 concentration was almost at the same level in both the north and south cities (Figures 2.6, 2.7 and 2.8).

Figure 2.5 - Air pollution trends in major cities of China, 1991–1998



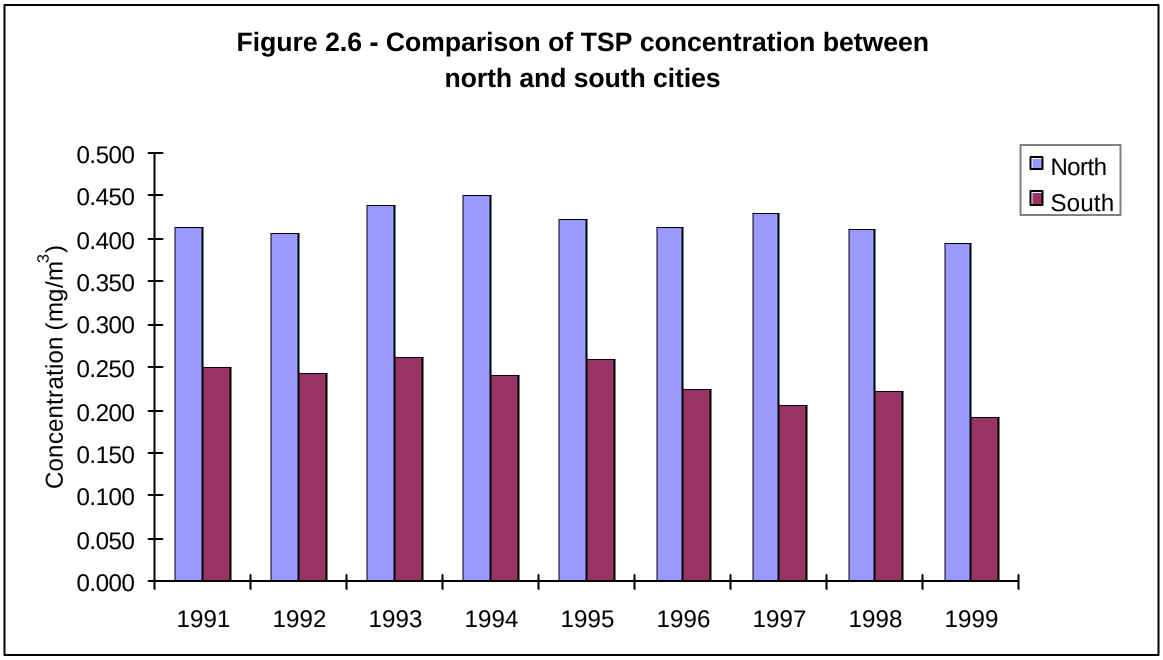


Figure 2.6 - Comparison of TSP concentration between north and south cities
Concentration (mg/m3)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1991
1992
1993
1994
1995
1996
1997
1998
1999
North
South

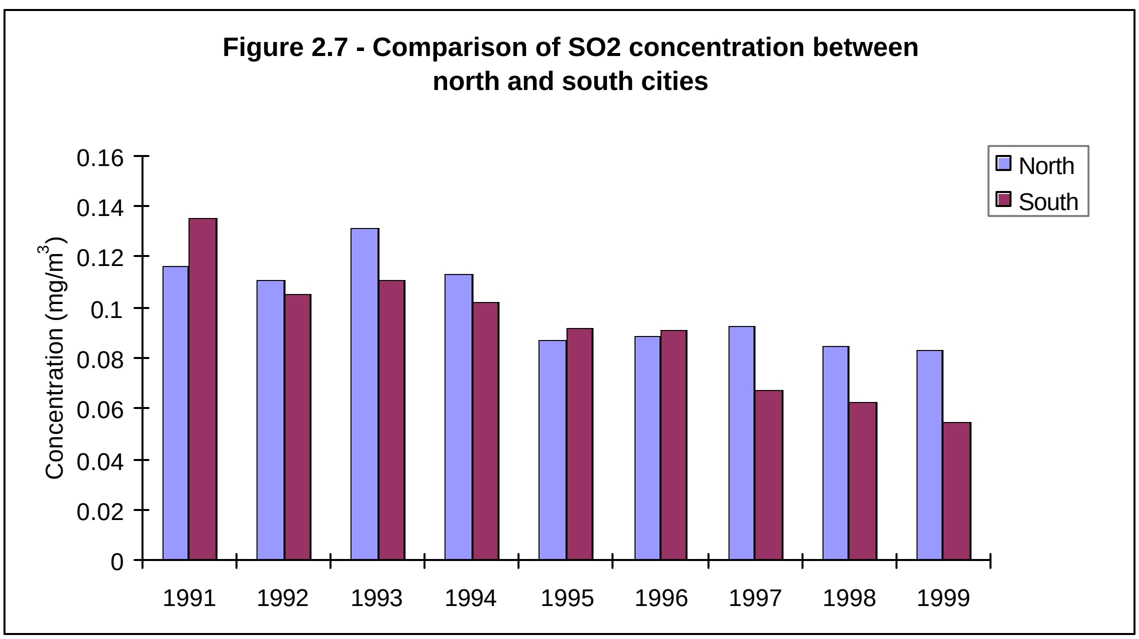
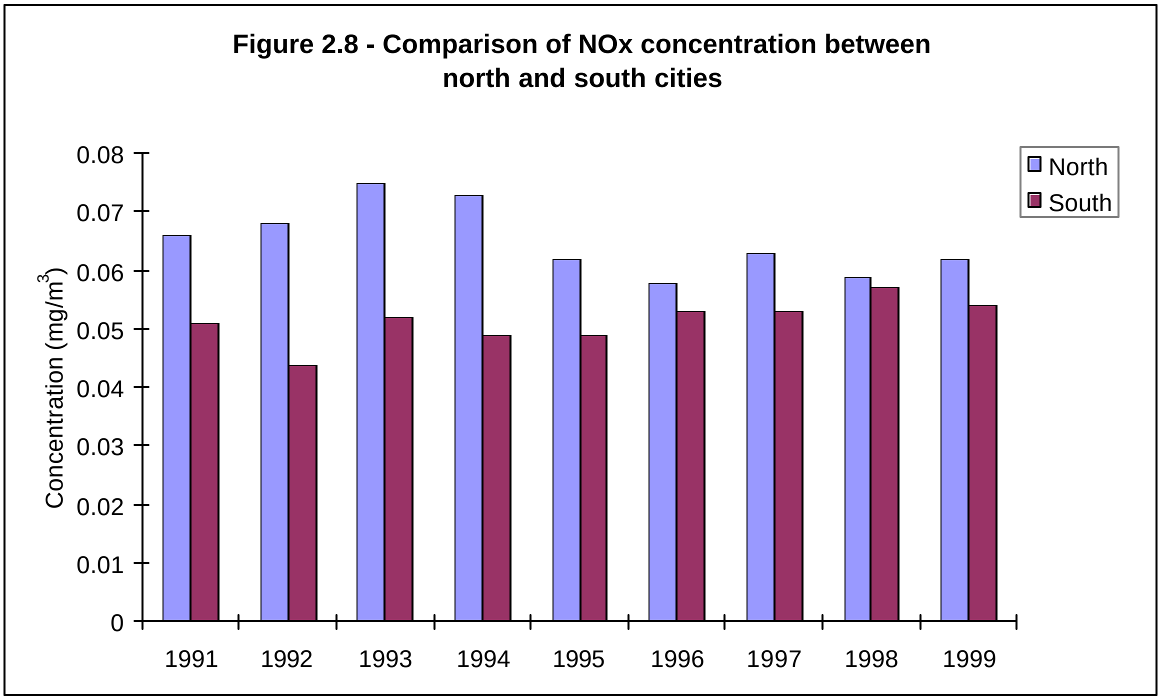


Figure 2.7 - Comparison of SO2 concentration between north and south cities
Concentration (mg/m3)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
North
South



Status of air quality in major Chinese cities

The air quality in major cities in China reflects the level of development in the last 10 years from 1991 to 1999. The annual TSP and NOx concentration in Beijing had increased slightly, while the annual SO_2 concentration was kept stable (Figure 2.9). This increase of TSP may be attributed to sand storms occurring especially in spring. In Beijing as in other urbanized areas, much effort has been made to control coal consumption and industrial waste gas emission and now most urban residents are using natural gas instead of coal. Even in Taiyuan and Xi'an, the two worst polluted cities due to coal burning, various control measures have been adopted which improved the situation somewhat (Figures 2.10 and 2.11). As an industrial city, Shanghai's air pollution was due largely to coal combustion and waste gas emission from industries. From 1991 to 1999, TSP and SO_2 concentrations have decreased, while NOx concentration has increased from 59 $\mu g/m^3$ to 105µg/m3 possibly due to an increase of motor vehicles (Figure 2.12). The main air pollutant in Guangzhou city is also NOx, with concentration above 100 $\mu g/m^3$ (Figure 2.13), while the annual TSP concentration has been decreasing to below 200 $\mu g/m^3$, Class II National Standard for Air Quality.

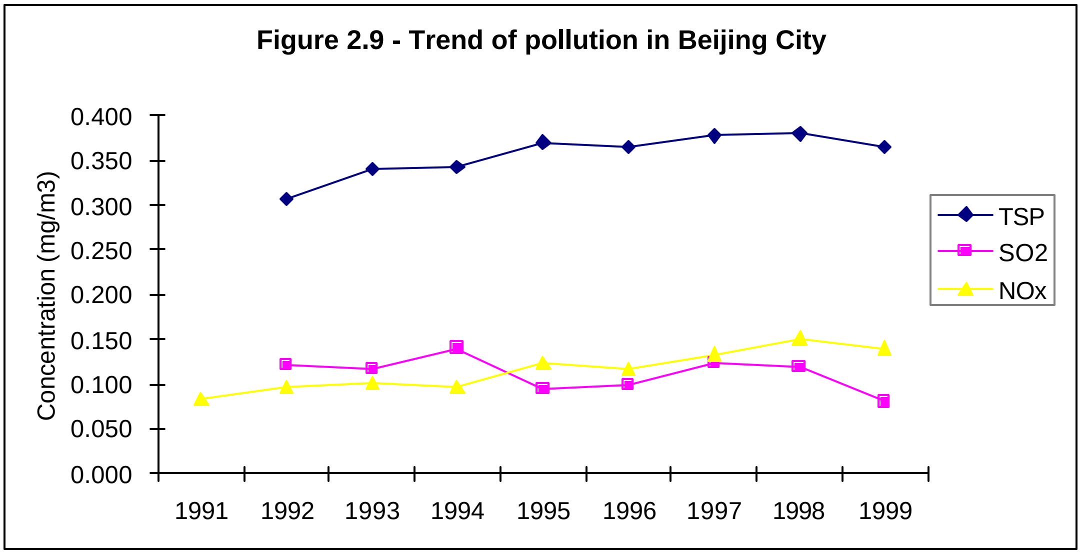


Figure 2.9 - Trend of pollution in Beijing City
Concentration (mg/m3)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1991
1992
1993
1994
1995
1996
1997
1998
1999
TSP
SO2
NOx

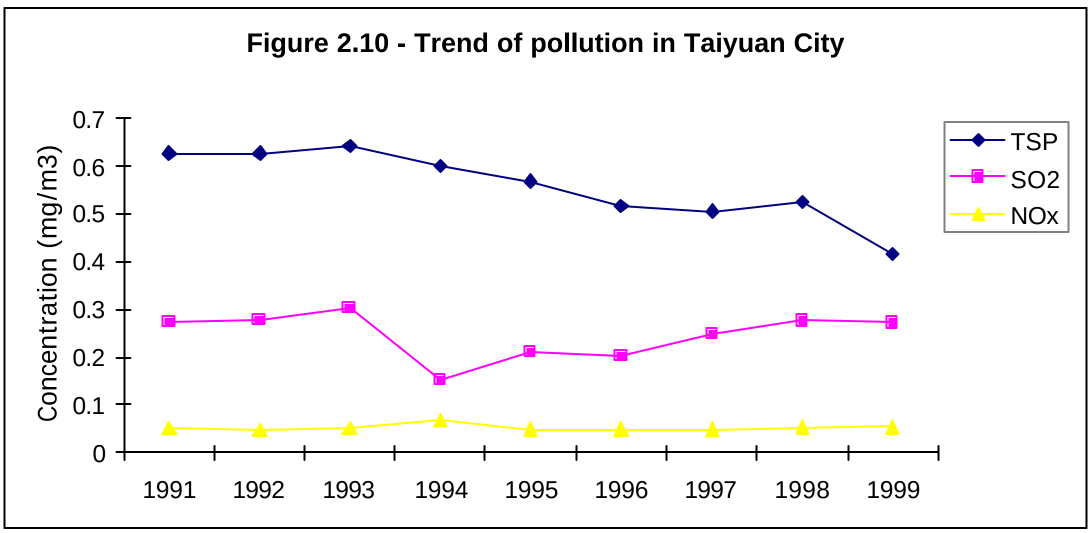


Figure 2.10 - Trend of pollution in Taiyuan City
Concentration (mg/m3)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
TSP
SO2
NOx

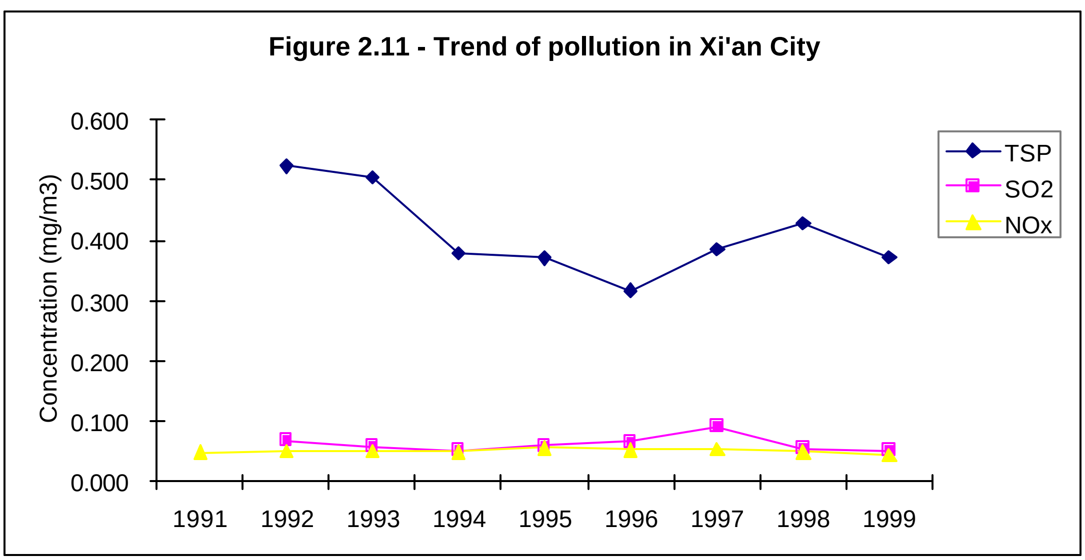


Figure 2.11 - Trend of pollution in Xi'an City
Concentration (mg/m3)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
1991
1992
1993
1994
1995
1996
1997
1998
1999
TSP
SO2
NOx

Figure 2.12 - Trend of pollution in Shanghai City

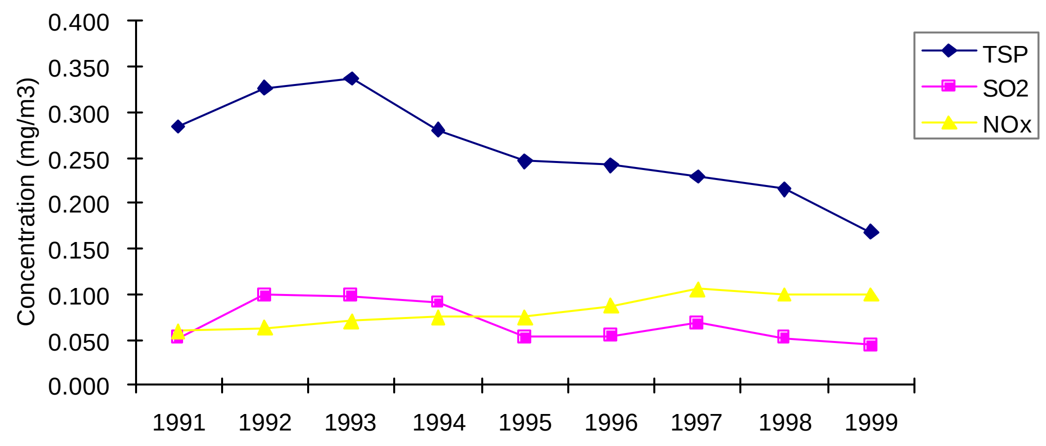
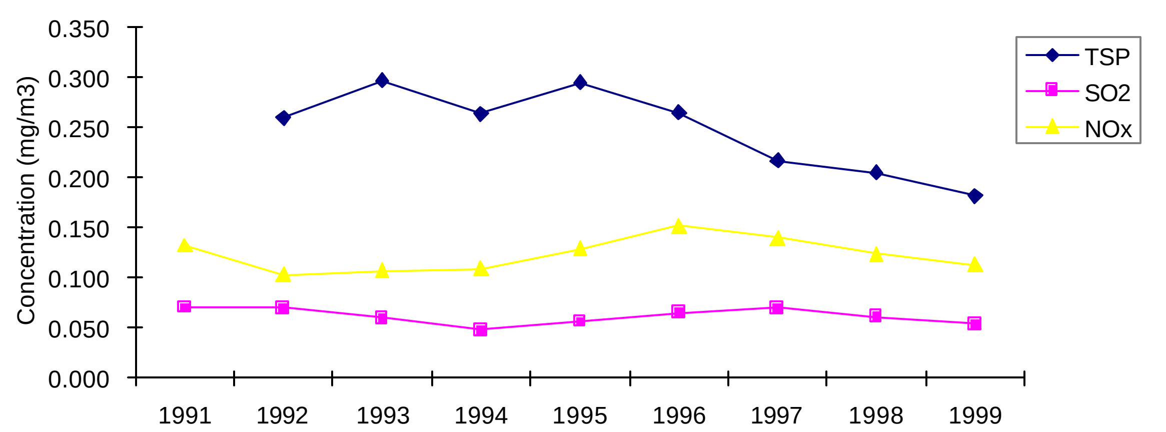


Figure 2.13 - Trend of pollution in Guangzhou City



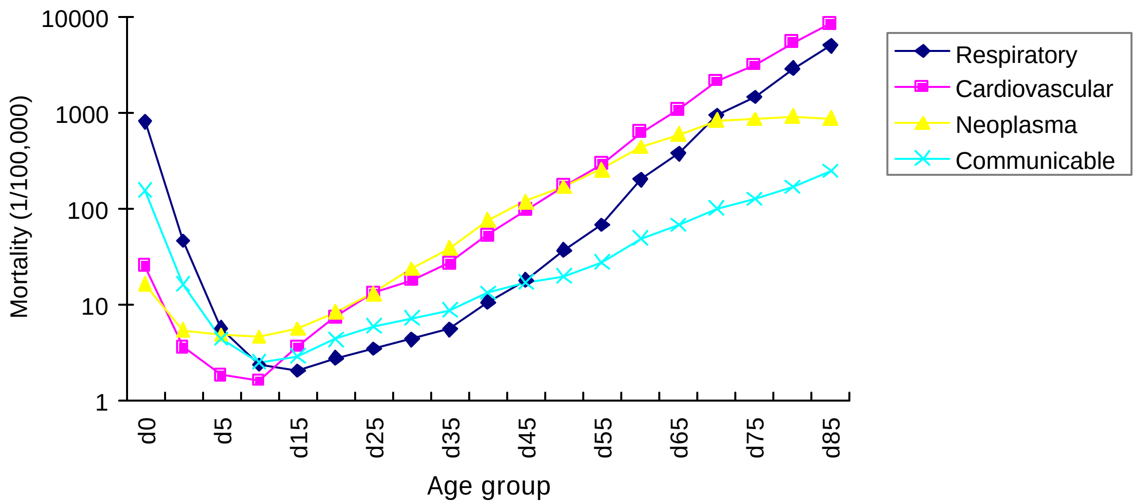
Relationship between TSP and PM10

Two thirds of the total suspended particulates (TSP) are suggested to consist of particles with diameter of less than 10 microns (PM10) in China. These finer particles are much more harmful to human health than the coarse particles. In Xi'an city, the proportion of PM10 in TSP was in the range of 60 to 70%. In Taiyuan city, the proportion of PM10 in TSP is much higher, ranging from 74 to 78% in summer and 81 to 87% in winter. Furthermore, the harmful components such as chromium, lead, cadmium, arsenic, and benzo(a)pyrene, are mainly in PM10. The study in Taiyuan suggested that 70 to 80% of BaP, As, Pb and Cr accumulate in PM10. There is evidence of elevated concentrations of sulfates, nitrates and ammonium salts in PM10 in Xi'an during winter.

Mortality cause-specific by various age groups

The older population usually has higher mortality rates from many causes. According to the Chinese disease surveillance report, the mortality of respiratory diseases, cardiovascular diseases and neoplasm is higher in 60~84 age group. However, children under 5 years old are sensitive to respiratory diseases and communicable diseases as shown in Figure 2.14.

Figure 2.14 - Mortality caused specific by age group in China,1991-1998



According to the annual disease mortality in the 60-84 age group in the 28 major cities, the region with the highest mortality due to respiratory diseases is the southwest, followed by the eastern and southern parts. Cardiovascular diseases are highest in the northeast, central and southern areas, and for neoplasm it is the east, central and northeast (Figures 2.15, 2.16 and 2.17).

Although the distribution of diseases is not the same as the air pollution profile, there are cities where air pollution is severe and a correspondingly high mortality rate from respiratory diseases, cardiovascular diseases and neoplasm. These cities are Guiyang, Lanzhou, Guangzhou, Zhengzhou and Wulumuqi. It is possible that many factors other than air pollution may affect the disease mortality rate, e.g., health service, poverty, culture and climate.

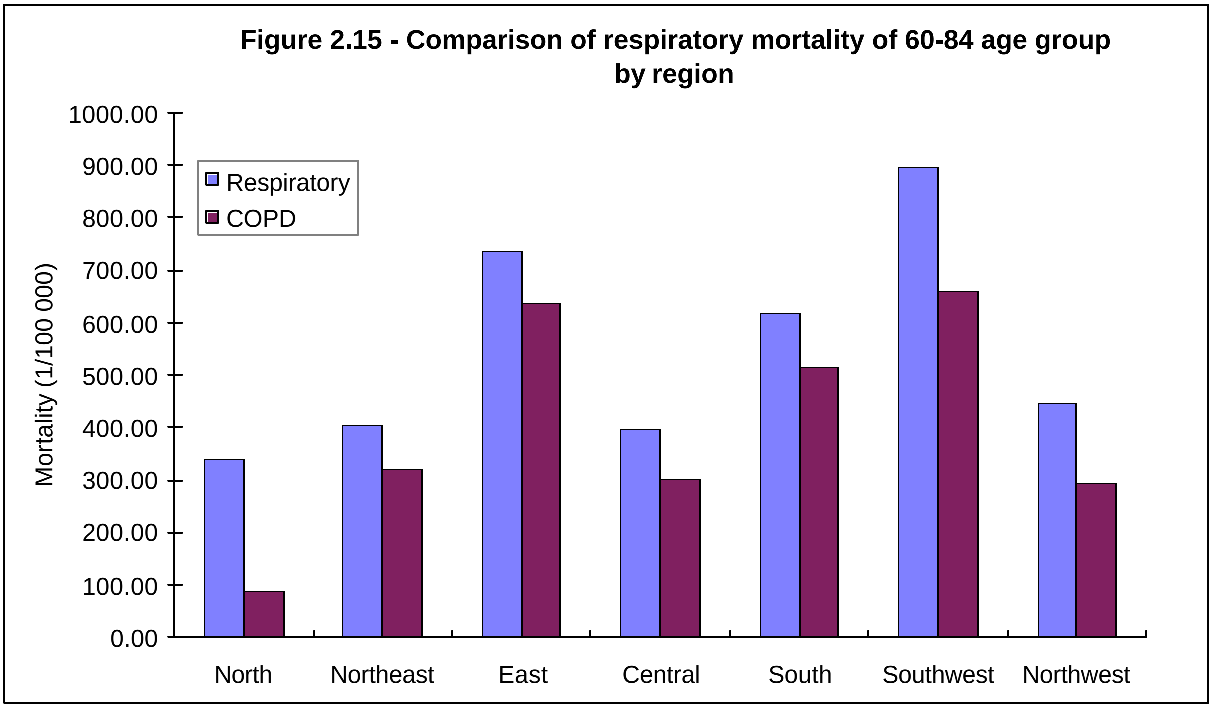


Figure 2.15 - Comparison of respiratory mortality of 60-84 age group by region
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Mortality (1/100 000)
Respiratory
COPD
North
Northeast
East
Central
South
Southwest
Northwest

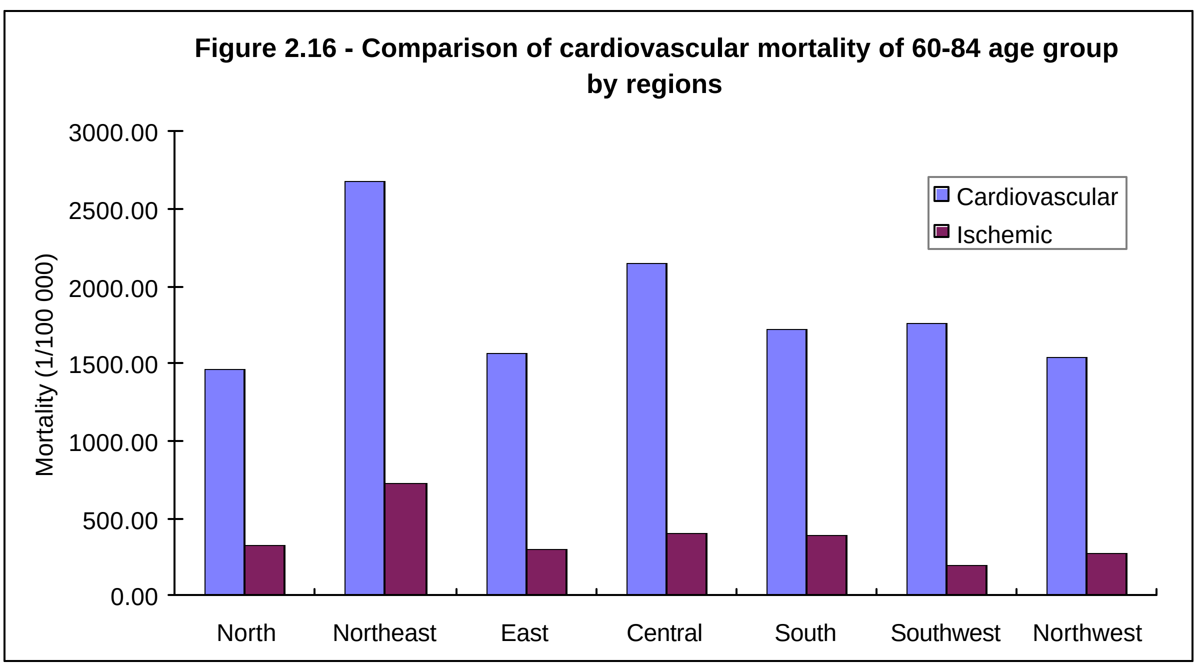
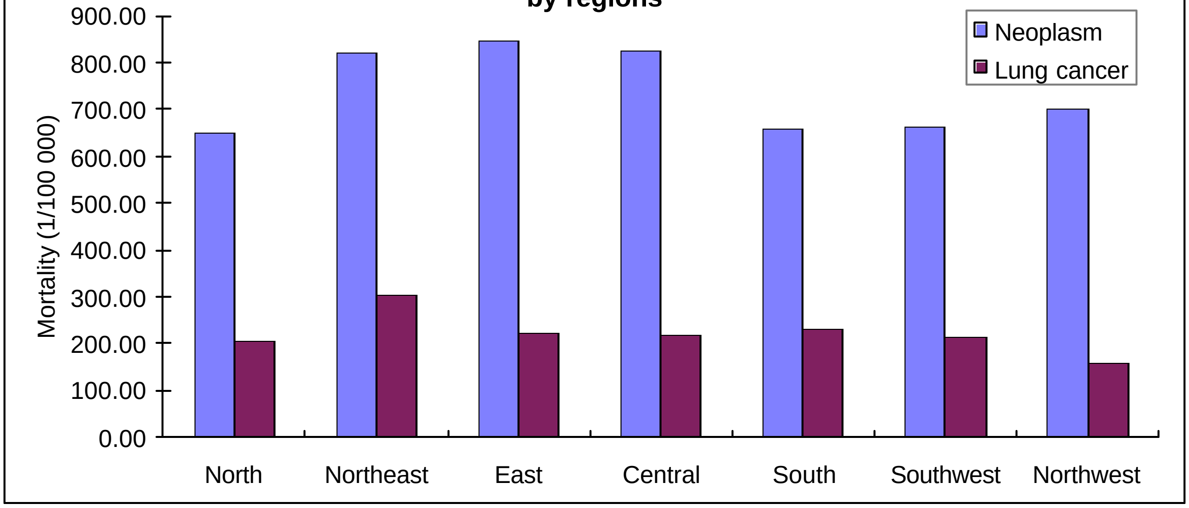


Figure 2.16 - Comparison of cardiovascular mortality of 60-84 age group by regions
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
Mortality (1/100 000)
Cardiovascular
Ischemic
North
Northeast
East
Central
South
Southwest
Northwest

Figure 2.17 - Comparison of neoplasm mortality of 60-84 age group by regions



Outdoor and indoor air pollution and health

Air pollution, both indoor and outdoor, was identified to be a major risk factor for respiratory diseases, the leading causes of death in China. However, it is difficult to pinpoint which source has a greater health impact. It was estimated that 289,000 premature deaths could be prevented each year if air pollution concentration were reduced to standard levels (World Bank, 1997). Globally, about 43% of the total burden of disease due to environmental risks affects children under 5 years old, even though they constitute only 12% of the total population (Smith *et al*, 1999).

There are several studies that provided evidence of the complex relationship between air pollution and human health in China. In a study in Beijing, it was found that the risk of mortality from COPD increased 38 percent with the doubling of particulate emissions (Xu *et al*, 1994). The study on the relationship between air pollution and chronic bronchitis and asthma in Shenyang showed that the prevalence rates of chronic bronchitis and asthma were 24.4% and 13.6%, respectively, in heavily polluted region (Yin, 1993). This is illustrated more in Table 2.4. Another compelling evidence was shown recently in a study in Taiyuan city, Shanxi province that currently has the highest level of air pollution in China. According to the comparison of prevalence rates of respiratory diseases and respiratory tract symptoms, the prevalence rates of bronchitis and COPD are higher in heavily polluted areas than those in relatively clean areas (Jin, 2000).

Table 2.4 Prevalence of respiratory diseases of residents due to air pollution, smoking, and coal-burning in Shenyang, 1993

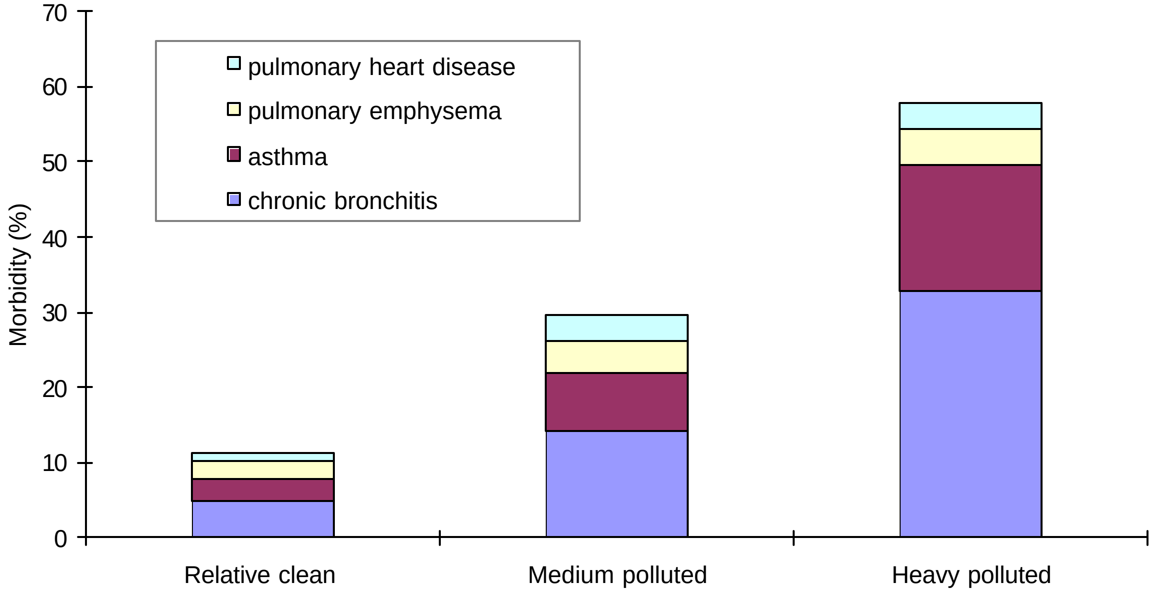
Air Pollution	Smoking	Coal-Burnin g	Disease	Prevalence, %			p
				Control	Medium Polluted Area	Heavily Polluted Area	
+	-	-	Chronic bronchitis	2.3 (1.00)	7.0 (3.04)	24.4 (10.61)	<0.01
+	+	+	Chronic bronchitis	6.6 (2.87)	19.4 (8.43)	50.0 (21.74)	<0.01
+	-	-	Asthma	1.9 (1.00)	2.8 (1.47)	13.6 (7.16)	<0.01
+	+	+	Asthma	5.2 (2.74)	8.7 (4.58)	24.6 (12.95)	<0.01

Source: Yin, 1993

Air pollution and COPD

In China, chronic obstructive pulmonary diseases (COPD) induced by air pollution was found to be a major cause of illness. Many studies have confirmed that the prevalence of chronic respiratory problems, such as chronic bronchitis, increases in the heavily polluted regions. A survey carried out on the relationship between COPD morbidity of population above 40 years old and air pollution in Shenyang showed that the morbidity of COPD, especially chronic bronchitis and asthma, markedly increased with the degree of air pollution. The two diseases, as shown in Figure 2.18, had morbidity of 5.0% and 2.9%, in the relatively clean regions, while in the heavily polluted regions, the morbidity data were 32.7% and 16.7%, respectively (Jin, 2000). In Shanghai, it was reported that given a constant concentration of SO_2 in ambient air, any increase of TSP by 0.1 mg/m^3 would have a corresponding increase in the odds ratio or likelihood of coughing (1.20), vomiting (1.23), stifling (1.13), chronic bronchitis (1.29) and pulmonary emphysema (1.59), respectively (Hong, 1991).

Figure 2.18 - Morbidity of COPD in population above 40 years old in polluted area, 1993



Source: Jin, 2000

Indoor air pollution and lung cancer

The relationship between indoor air pollution and lung cancer has been studied extensively in China and many parts of the world. Xuanwei county in Yunnan province has the highest mortality of lung cancer in China, and even in the world. The annual age-adjusted lung cancer rate in Xuanwei for the period 1973-1979 was 26.49/100,000 comprising 49.5% of total malignant neoplasms (He, 1990). A more specific comparison is found in Table 2.5. Xuanwei residents, especially females, were exposed to very high indoor particulate concentrations - more than 100 times the US ambient air 24-hour standard. The particulates from smoky coal burning are mainly less than 10 microns that remain longer in air, easily inhalable and can be effectively deposited in the lung (WHO, 1994; WRI, 1998). In rural Yunnan province, indoor particulate concentration due to coal burning was found to be as much as 270-5,100 microgram per cubic meter. This concentration was the highest among twelve selected places throughout China (WHO, 1997).

Another by-product of indoor burning are high levels of carcinogenic polyaromatic hydrocarbon (PAH) such as benzo(a)pyrene or B(a)P, which is the major risk factor of high lung cancer prevalence in Xuanwei. The B(a)P indoor concentrations during cooking are comparable to occupational exposure levels, such as those in coke oven plants (WHO, 1994; Lan *et al*, 1990).

Table 2.5 Age-adjusted mortality of lung cancer in Xuanwei, Yunnan province

Xuanwei Incidence Areas	Mortality (per 100,000)	National lung cancer mortality/100,000
Low	5.98	Male – 6.28
Medium	20.90	Female – 3.20
High	126.06	

Source: He, 1990

Lead poisoning and children's health

Lead is a known toxicant causing neurological, reproductive and carcinogenic effects. According to a three-year national survey of 28 selected cities in China, blood lead levels of more than half of Chinese urban children exceeded the WHO standard of 100 μg/L (Wu, 2000). WHO has indicated that learning impairment as well as behavioral abnormality can happen following postnatal exposures that result in blood lead levels of 109 to 330 μg/L.

Dose-response relationship between air pollution and cause-specific mortality according to the ecological correlation analyses

Air pollution was suspected to be one of the leading risk factors for respiratory diseases, leading causes of death in China. Respiratory diseases include chronic obstructive pulmonary disease (COPD), lung cancer, pulmonary heart disease, and bronchitis. However, men and women have similar rates of these diseases, despite women's lower smoking rates, thus providing evidence that this high disease burden is related to pollution. In this study, the Pearson correlation coefficients between air pollution and mortality of some related diseases also show such relationship. The Pearson correlation coefficients between air pollution (TSP, SO_2, NOx) and mortality of respiratory diseases, COPD, pulmonary heart disease, chronic pulmonary heart disease, cardiovascular disease, ischemic heart disease, neoplasm and lung cancer among total age-group and 60-84 age-group are shown in Table 2.6. It indicated that SO_2 is significantly correlated with respiratory disease and lung cancer mortality of over 60 years old group ($p<0.05$), which suggests correlation between air pollution and mortality.

Further analysis on the log-log correlations are also indicated in Table 2.7 that logarithmic SO_2 was significantly correlated to logarithmic mortality of respiratory disease, cardiovascular disease, ischemic heart disease, neoplasm and lung cancer of 60-84 age-group. However, TSP is suggested to correlate weakly with acute and chronic pulmonary heart disease among people aged over 60 years. In this case, it should be explained that the disease mortality is due to many factors and air pollution only contributed partially.

Furthermore, it is extremely difficult to distinguish which sources of air pollution have the greatest impact on human health, indoor or outdoor. In urban areas, there is a great deal of exchange between outdoor and indoor air, both of which are polluted from different sources - indoor primarily from the burning of coal for cooking and heating. In this study, the correlation between industrial and residential coal consumption and waste gas emission with diseases mortality were also analyzed. The result showed that the amount of residential coal consumption and waste gas emission is significantly correlated to neoplasm mortality 60-84 age group.

The 28 cities were divided into two groups, highly polluted cities and less polluted cities, according to whether the TSP and SO_2 concentration exceeded the guideline. The comparison of mortality caused-specific between highly polluted cities and less polluted cities was analyzed by General Linear Model (GLM). Although it shows no significant difference in mortality between the two categories, the mortality of respiratory disease, cardiovascular disease and neoplasm is higher in highly polluted cities than that in less polluted cities (Table 2.8). After summing up the deaths in each group, the $?^2$ analysis showed that mortality of respiratory disease, cardiovascular disease, lung cancer and neoplasm is significantly different between highly polluted cities and less polluted cities (Tables 2.9 and 2.10).

Table 2.6 Pearson correlation coefficients between air pollution and mortality of related diseases (upper: coefficient; lower: significance)

	Mortality	TSP	SO_2	NOx
Total age group	Respiratory disease	-0.2191	0.1358	-0.0737
		0.2626	0.4907	0.7093
	COPD	-0.2806	0.1400	-0.1487
		0.1481	0.4772	0.4501
	Cardiovascular disease	-0.1414	-0.0320	0.0654
		0.4728	0.8716	0.7408
	Ischemic heart disease	-0.0805	-0.1379	0.1333
		0.6840	0.4839	0.4988
	Pulmonary heart disease	0.1480	-0.0507	0.2659
		0.4521	0.7979	0.1714
	Chronic pulmonary heart disease	0.1611	-0.1838	0.1898
		0.4128	0.3491	0.3333
	Lung cancer	-0.1822	0.1827	0.0208
		0.3534	0.3519	0.9162
	Neoplasm	-0.1807	0.0351	-0.0180
		0.3574	0.8592	0.9276
60-84 age group	Respiratory disease	-0.1698	0.4008	-0.1028
		0.3876	0.0345	0.6025
	COPD	-0.25358	0.36859	-0.16029
		0.1929	0.0536	0.4152
	Cardiovascular disease	0.00871	0.33704	0.05320
		0.9649	0.0794	0.7880
	Ischemic heart disease	0.01571	-0.07422	0.11298
		0.9368	0.7074	0.5670
	Pulmonary heart disease	0.29665	0.01749	0.29293
		0.1253	0.9296	0.1303
	Chronic pulmonary heart disease	0.34130	-0.10631	0.21695
		0.0755	0.5903	0.2675
	Lung cancer	-0.11714	0.41246	0.05311
		0.5527	0.0292	0.7884
	Neoplasm	0.04745	0.34544	0.02825
		0.8105	0.0718	0.8865

Table 2.7 Pearson correlation coefficients between air pollution and mortality of related diseases (upper: coefficient; lower: significance)

	Mortality	TSP	SO_2	NOx
Total age group	Respiratory disease	-0.1401	0.1979	-0.1562
		0.4772	0.3127	0.4275
	COPD	-0.23639	0.22099	-0.15355
		0.2259	0.2584	0.4353
	Cardiovascular disease	0.14237	0.12076	-0.09897
		0.4699	0.5405	0.6163
	Ischemic heart disease	0.1122	0.33233	-0.05124
		0.5697	0.084	0.7957
	Pulmonary heart disease	0.36433	0.10157	-0.02527
		0.0566	0.607	0.8984
	Chronic pulmonary heart disease	0.33378	-0.10359	0.17051
		0.0956	0.6146	0.405
	Lung cancer	-0.0269	0.61944	0.01623
		0.8919	0.0004	0.9347
	Neoplasm	-0.04159	0.49777	-0.02132
		0.8336	0.007	0.9143
60-84 age group	Respiratory disease	-0.11712	0.44888	-0.14561
		0.5528	0.0166	0.4597
	COPD	-0.23145	0.29725	-0.14849
		0.236	0.1245	0.4508
	Cardiovascular disease	0.20007	0.38346	-0.10477
		0.3074	0.044	0.5957
	Ischemic heart disease	0.13942	0.49822	-0.05334
		0.4792	0.007	0.7875
	Pulmonary heart disease	0.36094	0.15828	-0.00433
		0.0592	0.4211	0.9826
	Chronic pulmonary heart disease	0.36782	-0.01234	0.19212
		0.0645	0.9523	0.3471
	Lung cancer	-0.04106	0.14593	0.13021
		0.8389	0.4677	0.5174
	Neoplasm	0.09387	0.62965	0.06969
		0.6347	0.0003	0.7245

Table 2.8 Comparison of mortality cause-specific between highly polluted cities and less polluted cities

	Mortality	Pollution Level	TSP		SO_2	
			Mean	SE	Mean	SE
Total age group	Respiratory disease	high	75.2	9.7	79.2	11.2
		low	73.0	20.8	68.1	13.9
	COPD	high	51.5	9.3	53.7	10.9
		low	58.9	20.0	51.4	13.5
	Cardiovascular disease	high	245.9	19.7	227.4	22.6
		low	223.2	42.3	264.0	28.1
	Ischemic heart disease	high	32.8	5.9	29.6	6.9
		low	28.3	12.7	35.7	8.5
	Pulmonary heart disease	high	18.1	3.4	18.0	4.0
		low	21.1	7.3	19.8	4.9
	Chronic pulmonary heart disease	high	51.2	6.4	47.0	7.6
		low	37.6	13.8	51.4	9.4
	Lung cancer	high	34.5	3.2	35.4	3.7
		low	24.9	6.8	28.7	4.6
	Neoplasm	high	127.5	9.1	129.0	10.6
		low	116.2	19.6	120.0	13.2
60-84 age group	Respiratory disease	high	558.5	83.9	630.2	96.3
		low	637.5	180.0	483.6	119.7
	COPD	high	391.7	80.2	439.1	94.1
		low	538.5	172.0	385.2	117.0
	Cardiovascular disease	high	1734.5	118.0	1719.0	137.4
		low	1654.8	253.0	1722.2	170.8
	Ischemic heart disease	high	242.7	40.4	232.4	47.3
		low	190.6	86.8	234.9	58.8
	Pulmonary heart disease	high	141.1	25.3	151.6	29.3
		low	146.6	54.3	127.4	36.4
	Chronic pulmonary heart disease	high	356.1	38.1	338.7	45.3
		low	258.9	81.7	338.8	56.3
	Lung cancer	high	221.0	20.9	231.0	24.0
		low	185.3	44.8	189.3	29.8
	Neoplasm	high	745.4	48.0	767.9	55.2
		low	661.0	102.9	672.2	68.6

SE – standard error

Table 2.9 Comparison of mortality cause-specific between SO_2 highly polluted cities and less polluted cities

	Pollution Level	Respiratory Disease	COPD	Cardiovascular Disease	Ischemic Heart Disease	Lung Cancer	Neoplasm
SO_2	High	635.54	457.70	1746.61	398.77	247.72	789.63
	Low	578.31	473.60	1802.76	380.58	197.93	691.16
?^{2}		17.04	1.74	3.92	2.69	34.43	41.21

Table 2.10 Comparison of mortality cause-specific between TSP highly polluted cities and less polluted cities

	Pollution Level	Respiratory Disease	COPD	Cardiovascular Disease	Ischemic Heart Disease	Lung Cancer	Neoplasm
TSP	High	630.48	474.29	1788.86	410.29	236.61	765.09
	Low	472.93	369.59	1542.94	231.80	165.06	648.75
?^{2}		50.85	29.72	43.66	102.06	28.00	22.65

When 7 regions were adjusted in the GLM model, logarithmic SO_2 is significantly correlated to the mortality of respiratory disease and neoplasm of total age group, and mortality of cardiovascular disease of 60-84 age group. The results are shown in Tables 2.11 and 2.12, and the dose-response relationships were also calculated, as shown in Figures 2.19 to 2.24. The line regression equations were obtained as follows:

$$\log(\text{mortality of respiratory disease}) = 0.3033 \log(SO_2) + 0.964$$
$$\log(\text{mortality of cardiovascular disease}) = 1.991 \log(SO_2) + 2.7426$$
$$\log(\text{mortality of neoplasm}) = 0.2523 \log(SO_2) + 1.5129$$
$$\log(\text{mortality of lung cancer}) = 0.5722 \log(SO_2) + 0.3149$$

Table 2.11 The dose-response relationship between logarithmic SO_2 and logarithmic mortality adjusted by region

		60~84 Age Group			Total Age Group		
		Male	Female	Total	Male	Female	Total
Respiratory	α	1.4245	1.3257	1.4343	0.9898	0.7956	0.9634
	β	0.5103	0.5137	0.4938	0.2948	0.3637	0.3033
	P value	0.0013	0.0011	0.0006	0.0487	0.0257	0.0367
COPD	a	1.1811	0.4768	0.5179	0.1541	-0.1844	-0.2033
	ß	0.3670	0.6433	0.6615	0.4308	0.5474	0.5867
	P value	0.1334	0.0014	0.0005	0.1247	0.0136	0.044
Cardiovascular	a	2.8468	2.6214	2.7426	2.0808	1.9617	2.0410
	ß	0.1635	0.2354	1.991	0.1238	0.1496	0.1320
	P value	0.0024	0.0007	0.0006	0.1328	0.1277	0.1308
Ischemic	a	1.8448	1.5675	1.5021	0.7813	0.9371	0.9462
	ß	0.3125	0.4204	0.4691	0.4260	0.3231	0.3394
	P value	0.0790	0.0099	0.0008	0.0058	0.0804	0.0243
Neoplasm	a	2.3308	1.8770	2.1356	1.6151	1.3602	1.5129
	ß	0.2596	0.3816	0.3170	0.2352	0.2750	0.2523
	P value	0.0013	0.001	0.0001	0.0014	0.0019	0.0008
Lung cancer	a	2.1971	1.3715	1.9285	0.5814	0.6790	0.3149
	ß	0.1089	0.3290	0.1811	0.5033	0.2911	0.5722
	P value	0.4767	0.0475	0.1801	0.0001	0.0871	0.0001

Table 2.12 The dose-response relationship between other environmental pollution and logarithmic mortality adjusted by region

		Residential Coal Consumption		Waste Gas Emission	
		60~84 Age Group	Total Age Group	60~84 Age Group	Total Age Group
Respiratory	a	1.8565	1.0415	1.1202	0.7849
	ß	0.2443	0.2208	0.3823	0.2308
	P value	0.0244	0.0286	0.0011	0.0494
COPD	a	1.1211	0.1943	0.2493	-0.4875
	ß	0.3125	0.3309	0.4694	0.292
	P value	0.0316	0.0271	0.0032	0.0111
Cardiovascular	a	2.8265	1.9314	2.8515	2.1458
	ß	0.1322	0.1522	0.0880	0.0492
	P value	0.0014	0.0082	0.0910	0.4935
Ischemic	a	1.6954	0.9289	1.018	0.5043
	ß	0.3132	0.2879	0.4198	0.3262
	P value	0.0016	0.0046	0.0001	00054
Neoplasma	a	2.5015	1.7077	1.8323	1.2034
	ß	0.1198	0.1329	0.2739	0.2371
	P value	0.0665	0.0185	0.0001	0.0001
Lung cancer	a	2.0805	0.09321	1.6413	-0.3285
	ß	0.0907	0.2330	0.1885	0.5214
	P value	0.1831	0.0385	0.1511	0.0001

Figure 2.19 - Correlation between respiratory disease mortality of total age group and SO2 adjusted by region

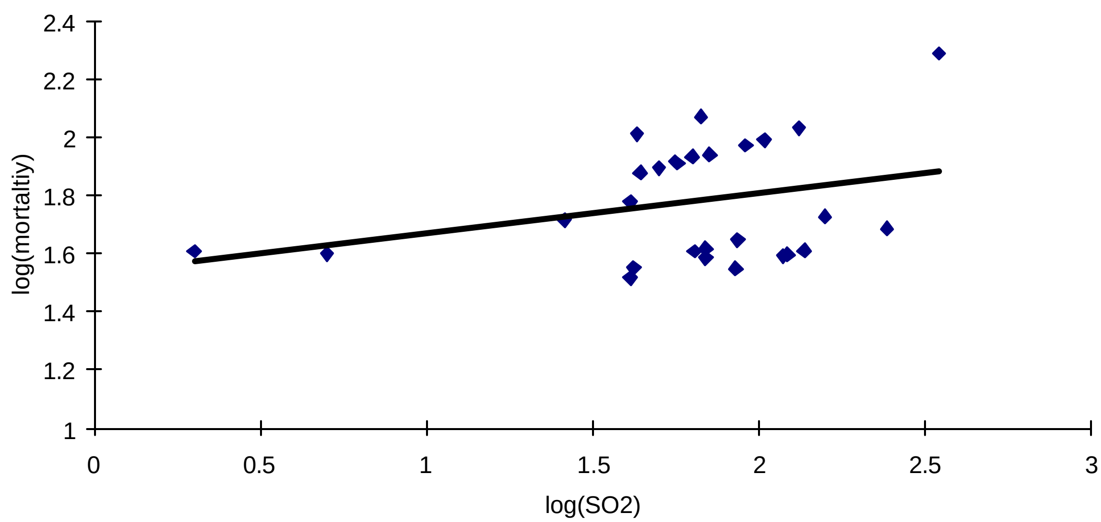


Figure 2.20 - Correlation between COPD mortality of total age group and SO2 adjusted by region

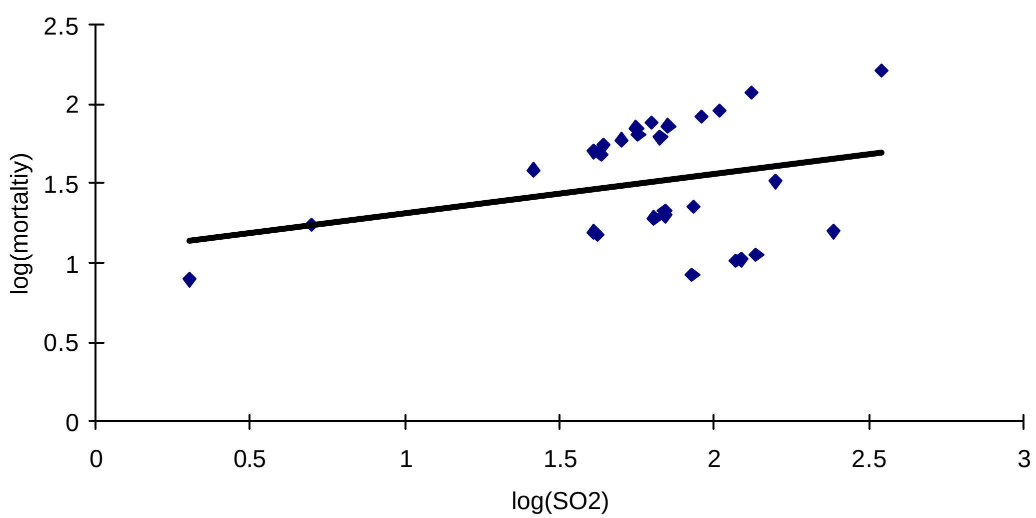


Figure 2.21 - Correlation between cardiovascular disease mortality of total age group and SO2 adjusted by region

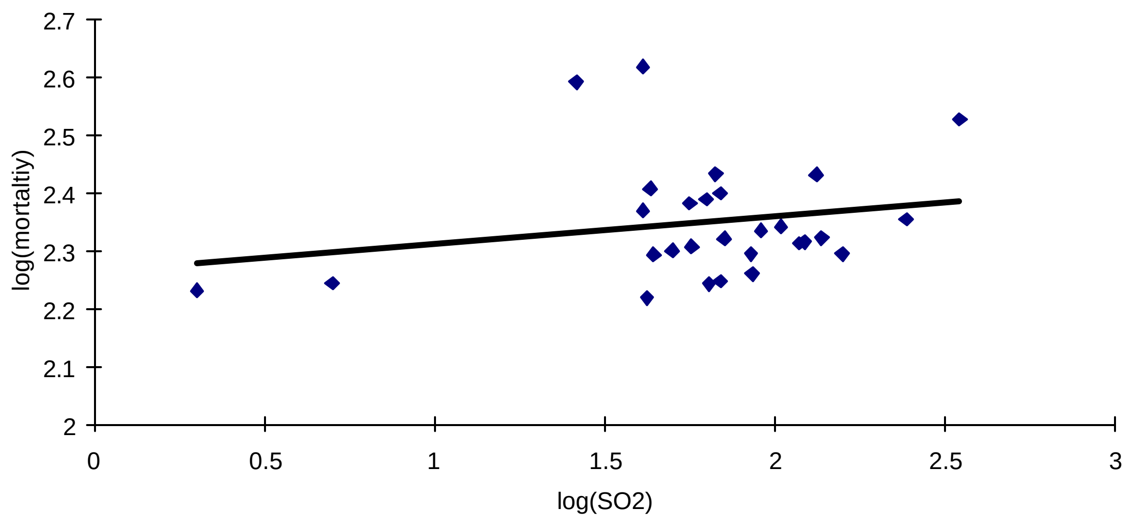


Figure 2.22 - Correlation between ischemic heart disease mortality of total age group and SO2 adjusted by region

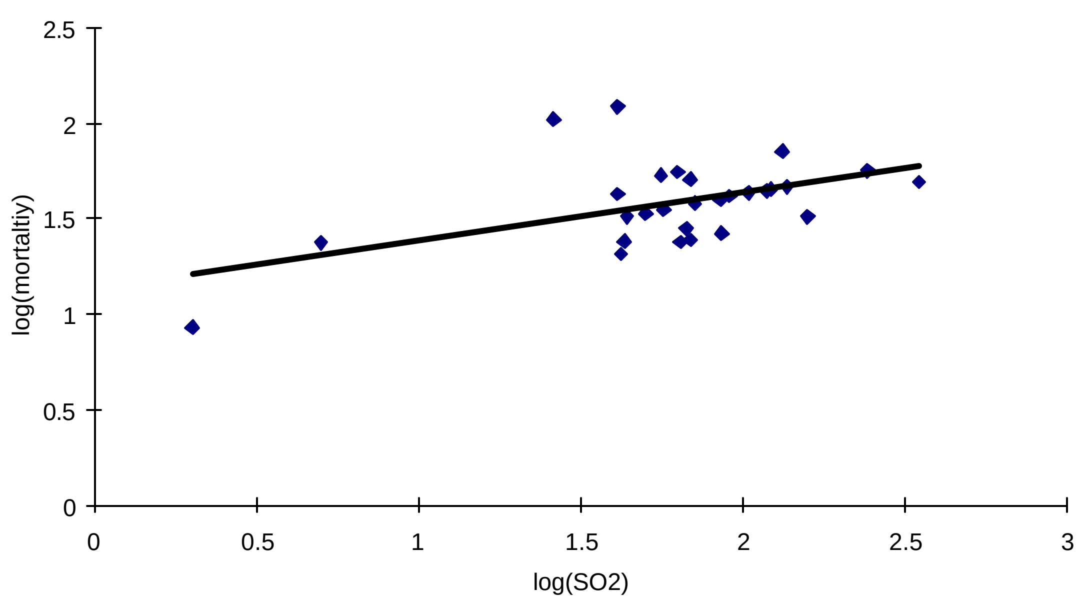


Figure 2.23 - Correlation between neoplasm mortality of total age group and SO2 adjusted by region

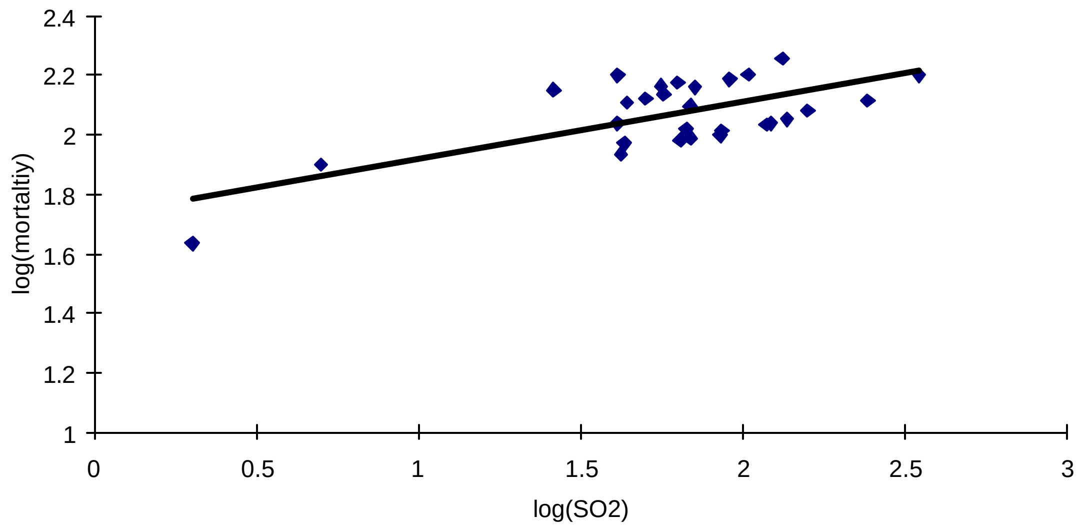
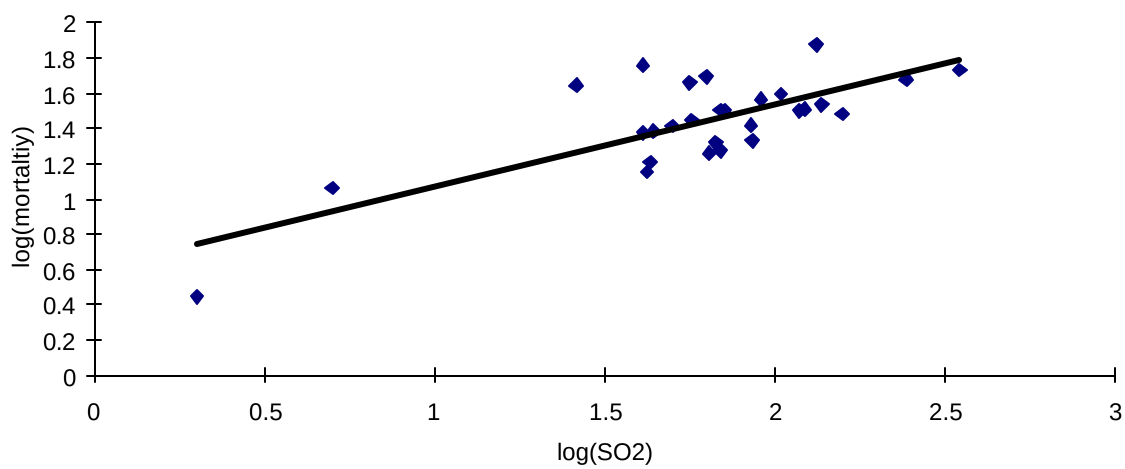


Figure 2.24 - Correlation between lung cancer mortality of total age group and SO2 adjusted by region



Estimation of excess deaths associated with air pollution

Another measure of air pollution's impact on health is the number of hospital admissions from respiratory diseases. This study found 346,000 hospital records associated with the excess levels of air pollution in urban areas. Table 2.13 summarizes the estimate of respiratory damage that could be avoided by meeting Class 2 air quality standards in China.

Table 2.13 Estimates of respiratory damage that could be avoided by meeting Class 2 air quality standards in China

	Urban Air Pollution	Indoor Air Pollution
Premature deaths	178,000	111,000
Respiratory hospital admissions	346,000	220,000
Emergency room visits	6,779,000	4,310,000
Lower respiratory infections or child asthma	661,000	420,000
Asthma attacks	75,107,000	47,755
Chronic bronchitis	1,762,000	1,121,000
Respiratory symptoms	5,270,175,000	3,322,631,000
Restricted activity days (years)	4,537,000	2,885,000

In this study, based on dose-response functions and Chinese Class 2 standard for air quality (concentration of SO_2 is 60µg/m^3), the excess death caused by air pollution was calculated in Table 2.14. It is estimated that the excess deaths from respiratory disease, cardiovascular disease (60-84 years old) and lung cancer in urban area in China caused by air pollution are 127,000, 205,000 and 44,000 respectively, or a total of 367,000 within the 28 DSP sites.

2.2 Water Pollution and Health

Pollution of water resources

Each year, large amounts of pollutants are dumped into China's water bodies from municipal, industrial, and agricultural sources. From 1981 to 1995, the amount of industrial wastewater increased by 27.8%. Although the amount of wastewater discharged from regulated industries has leveled off since the early 1990s, discharges from TVEs and municipal sources have increased rapidly as discussed in the next section. In 1999, the total amount of wastewater discharge was up to 40.1 billion tons, causing extensive pollution of water bodies. About 25,000 km of Chinese rivers failed the water quality standards for aquatic life. On the other hand, treatment of municipal sewage lags far behind that of industrial wastewater. In 1999, China had 266 modern wastewater treatment plants with treatment capacity accounting for 14.7% of the total 20.4 billion tons of domestic sewage. Beijing has one secondary sewage treatment plant, with a capacity of 500,000 tons, which cannot keep pace with the increasing amounts of sewage in the city.

Table 2.14 The estimated excess death caused by air pollution in urban areas of China (mean SE)

Province	Excess death from respiratory disease of total age people	Excess death from cardiovascular disease of aged people	Excess death from neoplasm of total age people	Excess death from lung cancer of total age people
Anhui	5015	1811	4261	307
Beijing	632	2574	1484	885
Fujian	3399	2408	3011	329
Gansu	700	2135	671	0
Guangdong	14496	22047	15787	7452
Guangxi	4257	5682	4542	2049
Guizhou	12835	7652	5332	2563
Hainan	133	0	0	0
Hebei	1226	4179	2868	1757
Heilongjiang	3484	27270	8571	3881
Henan	1035	11337	5230	1637
Hubei	183	17893	3261	406
Hunan	11101	14187	13167	7888
Inner Mongolia	309	689	731	412
Jiangsu	9553	5369	8781	1255
Jiangxi	6029	3608	6227	1649
Jilin	3395	24075	8137	4331
Ningxia	141	308	93	0
Qinghai	52	129	0	0
Shaanxi	782	1643	406	0
Shanghai	6537	6196	6323	1216
Shanxi	1542	2980	3550	2416
Sichuan	24846	21988	3823	0
Tianjin	502	1928	1178	707
Tibet	28	0	0	0
Xinjiang	1157	2921	1571	479
Yunnan	4610	4115	136	0
Zhejiang	8992	9417	9102	2192
Total	126966 (5770)	204542 (8136)	118246 (4121)	43812 (2125)

According to the monitoring result for surface water quality in 2,222 river sections in 1998, only 37% of sections meet Grade I, II and III surface water standards, and 63% of river sections did not meet the Grade IV and V surface water standards. Among them, the main pollution parameters are ammonia, nitrogen, potassium permanganate and volatile hydroxybenzene. The river waters are unsuitable even for industrial or agricultural use. About 90 percent of the sections of rivers around urban areas were seriously polluted. Because heavy industry is concentrated in northern China, the major river systems in the

North are more heavily polluted than those in the South. In 1999, there were as much as 13.89 million tons of COD discharged into water bodies.

Pollution of drinking water

The majority of Chinese urban and some suburban residents now have access to tap water, while the largest portion of the rural population still relies on hand- or motor-pumped wells. In rural areas, farmers fetch water directly from rivers, lakes, ponds, or wells, with little or no treatment at all. Large rivers are the most common source of urban drinking water, as well as the major source for rural residents in many parts of the country. According to the data from national surveillance for drinking water quality and water borne diseases in 1985, drinking water pollution in the country has become a major concern since only 40% of the population is being served with safe drinking water.

Over the past decade, the Government has launched a major initiative to improve access to safe drinking water in rural areas. From 1991 to 1995, the Government spent 14.45 billion yuan (US$1.35 billion) to improve the drinking water supply in rural regions. An investigation on quality of drinking water in 19 provinces in 1998 showed that the quality of dinking water in rural areas has been successfully improved. Around 70.6% of total population use groundwater, and 56.5% use community water supply. According to the investigated population, 32.3% of them were supplied with Grade I water, compared with 10% in 1985 (see Table 2.15). Although the rural population with access to tap water more than doubled, more than one half of those people still drank water that failed to meet safety standards.

Health impact of water pollution

Despite an overall decline in mortality of infectious diseases in China, the population still suffers from a number of diseases associated with inadequate drinking water quality and sanitation. For the past two decades, diarrhea and viral hepatitis, both diseases associated with fecal pollution, had been the two leading infectious diseases in China. In 1995, the incidence of hepatitis was 63 per 100,000, a 46 percent decrease from 1991. After a sharp drop from 1991 and 1992, the incidence of dysentery rose in 1994, due in part to deterioration of water quality. In 1991, typhoid fever incidence reached as high as 10.6 per 100,000. Although the incidence of waterborne diseases is still high compared with other countries, effective medical care has kept mortality low, averaging less than 0.1 per 100,000 (China Ministry of Public Health, Beijing, 1996).

Table 2.15 Population supplied with different grade water in rural areas, 1998 (1,000)

Form of water supply	Grade I	Grade II	Grade III	Failed Standard
Community water supply	856.5 37.2%	446.2 19.7%	188.3 8.17%	833.5 35.0%
Non-community water supply				
1. Machine-pump well	101.6 30.1%	58.0 17.2%	57.0 15.7%	122.0 37.0%
2. Handpump well	204.0 28.9%	140.3 19.7%	135.9 19.1%	230.9 32.4%
3. Open dug well	82.8 16.3%	65.6 12.3%	63.7 12.9%	302.2 32.4%
Total	1245 32.3%	710.0 18.4%	444.8 11.5%	1489 37.9%

Recent epidemiological studies suggest that exposure to organic and inorganic chemicals in drinking water may significantly contribute to chronic disease. Liver and stomach cancers are the leading causes of cancer mortality in rural China. Many studies in China and abroad have shown a strong association between drinking water pollution and cancer incidence and mortality. An example is a study conducted in Lujiang County, Anhui Province, where mortality rates for stomach and liver cancers were associated with the high levels of inorganic substances in surface water (Guili, 1996). A study on the relationship between water pollution and cancer mortality was performed in BaiYangDian. It was divided into three regions according to the quality of drinking water. The results indicated that neoplasm mortality in both moderately polluted area and heavily polluted area is significantly higher than that in control area. The mortality of esophagus cancer and liver cancer in a heavily polluted area is 3 times that in control area as shown in Figure 2.25.

In southern China, where communities depend largely from ponds or lakes for drinking water, the rates of digestive system cancer are very high. An investigation of 560,000 people in 23 villages and towns showed that between 1987 and 1989, cancer mortality was 172 per 100,000, which is much greater than the average mortality rates in rural China (Su Delong, 1980). Gastric, esophagus, and liver cancers accounted for 85 percent of all cancers. A compelling evidence showing the correlation between drinking water contamination and health is the liver cancer prevalence in Qidong County, Jiangsu Province. Qidong County has the largest number of cases of liver cancer morbidity with about 50 / 100,000 for many years. Since 1972, several investigations on the relationship between liver cancer morbidity of Qidong residents and drinking water quality had been performed. Results consistently showed the similar pattern that pond or lake waters are the most polluted, causing the highest morbidity of liver cancer as shown in Table 2.16 (Gu, 1988).

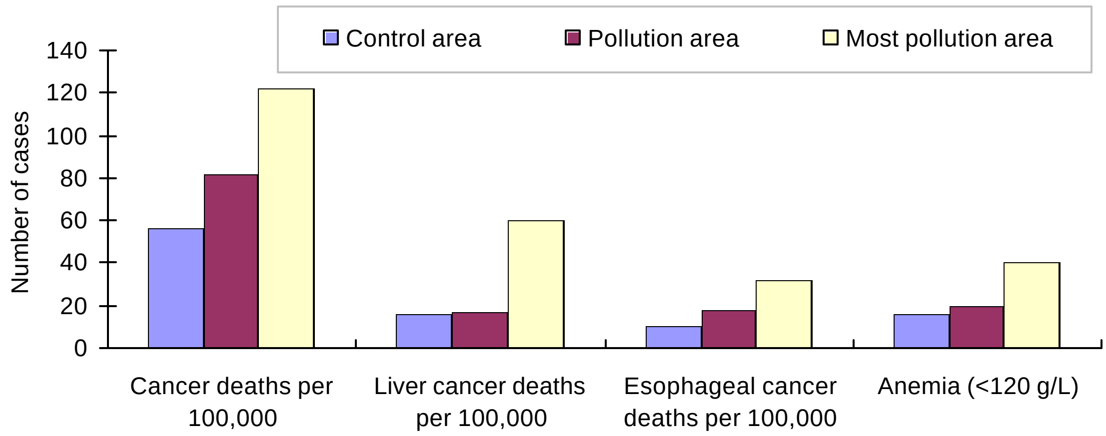


Figure 2.25 - Cancer deaths and anemia from sewage storage, Baiyangdian Lake

Table 2.16 Morbidity rates versus different sources of drinking water in Qidong County, Jiangsu Province

Source of Drinking Water	Morbidity (per 100,000)	
	Gu (1988) 1971-81	Su *et al* (1980) 1971-72
Pond / lake	141.40	101.35
Irrigation	72.32	64.57
River	43.45	42.64
Shallow well	22.26	0
Deep well	11.70	0

Fluorosis

Drinking water with a high level of fluoride can cause endemic fluorosis, such as dental and skeletal fluorosis. In China, this is the main cause of endemic fluorosis with the second major source of fluoride intake coming from coal burning. Fluoride levels as high as 5 times the WHO guideline (1 mg/L) have been found in the northeast and central parts of the country, except in Shanghai, Hainan, and Guizhou. In 1999, the Yearbook of Health in People's Republic of China reported a national total of 26,00 million cases of dental fluorosis and 1,15 million cases of skeletal fluorosis from drinking water sources.

An earlier nationwide survey carried out by the Institute of Environmental Health and Engineering of the Chinese Academy of Preventive Medicine in the early 1980s found that endemic fluorosis was prevalent in 238 cities, 1095 districts / counties and 125,817 villages with a total affected population of 85,610,000. Among 41,350,000 people who were investigated, 18,120,000 (43.82%) suffered dental fluorosis, and 830,000 (2%) suffered skeletal fluorosis.

In Jiangsu in 1984, a correlation study was carried out between the fluoride concentration in drinking water in some regions and the prevalence of dental and skeletal fluorisis. In Table 2.17, significant correlation with fluoride concentration in drinking water were found for dental fluorosis (correlation coefficient – 0.974) and for skeletal fluorosis (correlation coefficient – 0.829) (Chinese Academy of Preventive Medicine, 1988).

Table 2.17 The relationship between fluoride concentration in drinking water in Jiangsu and the prevalence of fluorosis, 1984

Fluoride Concn, mg/L	Population Investigated	Dental Fluorosis		Skeletal Fluorosis		Total	
		Cases	Prevalence %	Cases	Prevalence %	Cases	Prevalence %
<0.5	140,002	4,929	3.52	35	0.02	4,964	3.55
0.5-	35,331	4,066	11.51	54	0.15	4,120	11.66
1.0-	94,058	43,658	46.41	225	0.24	43,883	46.66
2.0-	43,976	26,069	50.28	538	1.22	26,607	60.50
4.0-	6,028	4,456	73.92	151	2.50	4,607	76.43
5.0-	10,005	8,379	83.75	46	0.46	8,425	84.20
Total	329,400	91,557	27.79	1,049	0.32	92,606	28.11

Source : Ministry of Health, 1984a

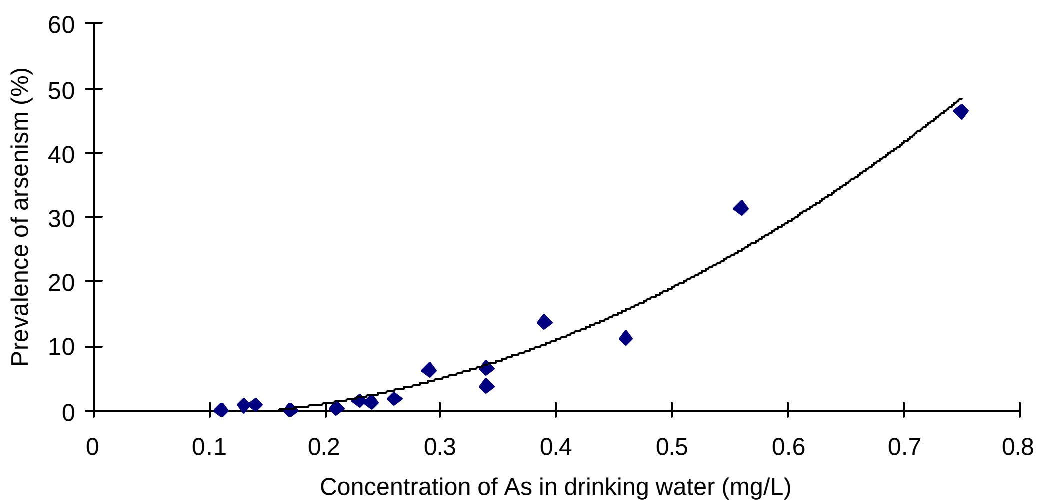
Arsenism

Endemic arsenism is a serious problem mainly in Xinjiang, Inner Mongolia, Shanxi, Guizhou, and Taiwan. In Xinjiang alone, some 2000 cases have been found, and 100,000 people are at risk of exposure to high levels of arsenic in drinking water. In Inner Mongolia and Shanxi, there is a high-arsenic region that is more than 1000 kilometers long and about 10 to 40 kilometers wide. This region includes 5 cities, 12 counties and 628 villages (farms) in Inner Mongolia with reported cases of 2,455 patients, and 2,620,000 people at risk (Wang, 1997).

In 1988, data from the "National Survey on Drinking Water Quality and Waterborne Diseases" conducted by the Chinese Academy of Preventive Medicine, indicated that around 14.7 million people in China had drunk water with arsenic concentration of more than 0.03 mg/L (the WHO guideline value is 0.01 mg/L). The main source of arsenic was groundwater wells (Zhang and Chen, 1997).

Most of the malignant neoplasms induced by arsenic are tumors affecting the epithelium tissues (skin, respiratory, digestive, and urinary systems), which account for 80% of total cases. Among all cases, skin cancer is the most prevalent (Ministry of Health, 1988). Endemic arsenism is a systemic disease caused by drinking water with high arsenic concentration and manifested as skin hyperpigmentation, hypopigmentation and hyperkeratosis. The Institute of Xinjiang Endemic Disease Preventive Research studied the relationship between arsenic concentration in drinking water (more than 0.1mg/L) and the prevalence of arsenism in 15 regions. They found a significant positive correlation between the arsenic concentration and the disease prevalence as shown in Figure 2.26. In Table 2.18, a similar pattern was observed whereby the mortality rate for malignant tumors was significantly correlated with the arsenic concentration in drinking water (Wang *et al*, 1996). In Hangmianhouqi Region, Inner Mongolia, the prevalence rate of 49.3% was found when the arsenic concentration was above 0.65 mg/L or 65 times the WHO guideline (Niu, 1996).

Figure 2.26 - The exposure - response relationship between arsenic and arsenism in Xinjiang, 1992



Source : Wang *et al*, 1996

Table 2.18 The relationship between mortality due to malignant neoplasms and drinking water arsenic concentration in Xinjiang, 1989-1995

Water Arsenic Concentration, mg/L	People Investigated	Total Deaths	Malignant Neoplasm	Mortality of Malignant Neoplasm, %
0.015	984	11	2	0.2
0.22	557	25	4	0.7
0.56	283	14	5	1.8
0.75	286	16	8	2.8

Source: Wang, 1997

Liver Cancer

In rural areas of China, severe biological pollution of drinking water sources has been found to cause both liver cancer and intestinal infectious diseases. The incidence of intestinal infectious diseases, such as hepatitis A, typhoid fever, bacillary dysentery, diarrhea and cryptosporidiosis, were observed to be 10-100 times more than in developed countries (Zeng *et al*, 1997). Domestic sewage and excreta, as well as agricultural runoff find their ways into surface waters such as rivers, lakes or ponds, which are the sources of drinking water for 25% of the population. Eutrophication of these bodies of surface water support the growth of cyanobacteria especially from July to September. Cyanobacteria can produce toxins such as microcystins which are potent liver cancer promoters and are directly hepatotoxic to poultry, livestock, animals and humans. Microcystins in drinking water cannot be completely removed by common disinfection and heating (Wang *et al*, 1995; Ling, 1999).

Compelling evidence showing the correlation between drinking water contamination and health is the liver cancer prevalence in Qidong County, Jiangsu Province. For many years, Qidong County has had the largest number of cases of liver cancer morbidity with about 50/100,000. Since 1972, several investigations on the relationship between the liver cancer morbidity of 765,602 Qidong residents and different sources of drinking water has been performed. Results consistently show a similar pattern that pond / lake waters are the most polluted and cause the highest incidence of liver cancer mortality as shown in Table 2.19 (Gu, 1988; Su *et al*, 1980).

Table 2.19 Morbidity rates versus different sources of drinking water in Qidong County, Jiangsu Province

Source of Drinking Water	Morbidity (per 100,000)	
	Gu (1988) 1971-81	Su *et al* (1980) 1971-72
Pond / lake	141.40	101.35
Irrigation	72.32	64.57
River	43.45	42.64
Shallow well	22.26	0
Deep well	11.70	0

2.4 Town and village enterprises and health

The rapid development of TVEs will have an enormous impact on China's water quality in the coming years. Although their development can be traced back to the late 1950s, these enterprises boomed in the past 10 years. The economic success of the TVEs has reduced poverty for millions of farmers, but they have also inflicted severe damage on the environment in rural China. Even though the Chinese Government has enacted a number of laws and policies to control and regulate industrial discharges, the government has not yet effectively regulated TVEs. The lack of regulation of township-and-village enterprises poses major threat to health and environment in the future and it should be given primary consideration.

By 1995, more than 7 million TVEs existed throughout China, with a total output of 5.126 trillion yuan (US$671 billion), accounting for 56 percent of the total industrial GDP - considerably more than the contribution of state-owned enterprises. The employees increased from 93 million in 1989 to 127 million in 1999, which means a growth rate of 36.5%. Development of TVEs play a very important role in absorbing surplus labor forces, increasing incomes of farmers and narrowing the gaps between the urban areas and the rural areas. In the meantime, however, large quantity of pollutants is generated, and inflicted severe damage on the environment in rural China.

A conservative estimate is that TVEs discharge more than half of all industrial wastewater in China - more than 10 billion metric tons. Most TVEs have no wastewater or hazardous waste treatment facilities, and since TVEs are widely scattered across vast rural areas, wastes from TVEs have the potential to affect the health of many people. A 1989-1991 investigation of the 10 leading TVE industries in seven provinces and municipalities showed that industrial wastes were discharged without any treatment and control. Table 2.20 indicates the discharge of pollutants by the TVEs in 1989 and 1997. The rapid increase of solid wastes discharge means that the TVEs have a low efficiency of resources and poor productivity. Large amount of waste discharge untreated were directly polluting the environment. Currently, the polluted land covers an area of 10-20 million hectares.

An analysis of the health of 860,000 people in the area revealed that the incidence rate of chronic diseases was between 12 and 29 percent, much higher than the national average for rural areas, which is approximately 9 percent. The total mortality in polluted areas averaged 4.7 per 1,000, higher than the average 3.6 in the control area. Life expectancy in the polluted areas was 2 years lower than in the control area as shown in Table 2.21. Although not definitive, evidence suggests that industrial pollution from TVEs could become a major threat to human health in China (Xu Fang et al., 1992).

At the end of the 1980s, the sanitation preventive station of Shandong province investigated the human health impact of coking plant and sulphur smelter, the results indicated that the risk of chronic diseases in pollution area by sulphur smelter and coking plant is 2.03 times and 2.24 times as much as in control area, respectively. The contribution risk of pollution is 50.74%, 31.51% and 55.36% for sulphur smelter, coking plant and both pollution, respectively (Table 2.22). The risk of acute diseases is also high in pollution area than that in control area (Table 2.23). The standardized life shorten rate of 18~60 age group in both coking plant and sulphur smelter polluted area is high than that in control area (Table 2.24).

Table 2.20 Discharge of main pollutants by Town and Village Enterprises in 1989 and 1997

Year	Pollutant - Wastewater			
	Wastewater (tons)	**% of national total**	**COD** (tons)	**% of national total**
1989	137,000	5.01	1,550,000	18.6
1997	384,000	16.93	4,070,000	37.93
Amount of Increase	2.8X			

Year	Pollutant - Exhaust Air					
	SO_2 (tons)	**% of national total**	**TSP** (tons)	**% of national total**	**Dust powder** (tons)	**% of national total**
1989	2,220,000	12.4	3,010,000	17.7		
1997	4,890,000	26.4	8,800,000	56.2	9,570,000	63.6
Amount of Increase	2.2X		2.9X			

Year	Pollutant - Solid Waste Generation and Discharge			
	Generated amount (tons)	**% of national total**	**Discharge** (tons)	**% of national total**
1989			16,000,000	17.3
1997	401,000,000	37.9	168,630,000,000	91.6
Amount of Increase			10.5X	

Table 2.21 Health impact of TVE pollution in residents around TVE (Comparison between polluted area and control area)

Occupation	RR of 15-day acute disease	RR of 1-year chronic disease	SMR (1986~1990)	PLLY under 15 years old		
				Male	Female	SRR
Electroplate	2.87***	4.61***	139**	3.02	3.30	1.88**
Cement plant	3.42**	1.38*	132**	3.84	2.90	1.30**
Printing and dyeing	0.88	0.84	132**	3.87	1.72	1.06
Asphalt felt plant	2.67***	2.97***	132**	3.84	2.90	1.30**
Coking plant	1.21	1.46*	113*	1.29	0.23	0.89
Sulphur smelter	2.51**	2.03**	143**	6.07	0.41	1.07
Lead smelter	1.33*	2.80**	120*	-1.15	0.27	0.79
Mercury smelter	1.09	1.35**	113*	0.50	0.42	1.12**
Zinc smelter	1.85**	1.31*	155**	2.69	1.93	1.26
Arsenic smelter	1.24	1.65**	—	—	—	—

*<0.05
**<0.01
***<0.001

Table 2.22 Comparison of chronic diseases in different TVE polluted areas

Area	Population Investigated	Patients	Prevalence (%)	RR^2	95% CI	P	AR%
Control	1385	80	5.78				
Sulphur smelter	388	52	13.40	2.03	1.49~2.79	<0.05	50.74
Coking plant	825	61	7.39	1.46	1.08~1.79	<0.05	31.51
Both sulphur smelter and coking plant	1469	205	13.96	2.24	1.77~2.85	<0.05	55.36

Table 2.23 Comparison of 15-day acute diseases in different TVE polluted areas

Area	Population Investigated	Patients	Prevalence (%)	RR^2	95% CI	P	AR%
Control	1429	50	3.50				
Sulphur smelter	404	33	8.17	2.51	1.65~3.83	<0.01	60.16
Coking plant	875	38	4.34	1.21	0.80~1.82	>0.05	
Both sulphur smelter and coking plant	1500	88	5.87	1.62	1.15~2.28	<0.01	38.27

Table 2.24 Comparison of PLLY rate in 18-60 age group

Area	Person Years Investigated	Deaths	Standar-dization PLLY	Rate of Standar-dization PLLY (%)	RR of Rate of Standar-dization PLLY	P	AR%
Control	32025	49	925	2.89			
Sulphur smelter	16410	21	530	3.23	1.12	>0.05	
Coking plant	26256	28	669	2.56	0.89	>0.05	
Both sulphur smelter and coking plant	14103	22	520	3.68	1.27	<0.05	21.26

In recent years, Guizhou Institute of Occupational Disease Prevention surveyed the pollution caused by mercury smelter, the result showed that the concentration of Hg in air reached around 0.20 mg/m^3, which exceeded 20 times the National Standard for Air Quality, the concentration of Hg in water is 0.0157mg/L, exceeded 14.67 times of National Standard for Drinking Water, and the concentration of Hg in food is 0.301mg/kg, exceeded 14.67 times of National Standard for Food. The physical test of workers in the mercury smelter indicated that the absorption of Hg is 50.7%, and the rate of chronic hydrargyrism is 37.61%.

There is therefore some evidence that TVEs has been, and will be, source of environmental pollution in the future which can contribute significantly to damages to the environment and to public health. TVEs' overall impact to China's economic development cannot be over emphasized but it is more prudent to strike a balance for a sustainable development.

Chapter 3
Proposed Health Risk Index for China

3.1 Provincial health risk index

The Health Risk Index (HRI) was estimated using approaches similar to those adopted by UNDP in calculating the Human Development Index (HDI) and the World Resources Institute in measuring potential exposure to health risks from environmental threats.

The HRI appears to be inversely proportional to the HDI. According to WRI, the quality of air, water, and food resources within a country can influence the health and potential exposure of populations to environmental health risks. In China, it is proposed to use potential exposure to air pollution, water pollution, poor nutrition, and access to health services as components of the Health Risk Index. Confounding factors, though important, were not considered here. Future refinement of the HRI methodology involves using more variables depending on availability of data.

As in other developing countries, there is scarcity of data in China for both environment and health statistics. In many cases, proxy indicators for human-environment relationships were applied, as well as the best available database such as published yearbooks, even if they may be of low quality or incomplete. In this section, we describe the methods in developing the indicators of environmental health risk using the best data available between 1995-1999.

For the 27 provinces and 3 autonomous cities (excluding Chongqing) of China, there are four indicators to estimate their likely health risk potential - exposure to polluted indoor and outdoor air, polluted water, poor nutrition and access to health services (Table 3.1). The fourth indicator, though not due to environmental conditions, can influence the total risk potential in terms of being able to provide timely medical attention. The results of the HRI are found in Tables 3.2 to 3.7.

Table 3.1 Indicators and Variables in Estimating the Health Risk Index

Indicators / Variables				
Air Pollution		Water Pollution	Poor Nutrition	Access to Health Services
Indoor	Outdoor			
Residential coal consumption	% of population living in cities exceeding WHO guidelines	% of population without access to safe water	% of under-5 children who are underweight	% of population without access to health services

Calculation of index for each province / city

1. Potential exposure to air pollution (indoor and outdoor)

   a) Indoor air pollution - residential coal consumption per family
   b) Outdoor air pollution

$$\% = \frac{\text{population living in cities exceeding the WHO air quality guidelines}}{\text{total population}}$$

Or in China, it becomes

$$\% = \frac{\text{urban population}}{\text{total population}} \times 100$$

Based on 1999 Environment Statistical Yearbook, almost all cities exceeded in at least one parameter (TSP, SO_2, NO_2).

2. Potential exposure to polluted water

   a) Percentage of population without access to safe water

$$\% = 100 \times \frac{(\text{urban population} \times \%\text{ of urban water samples exceeding standard}) + (\text{rural population} \times \%\text{ of rural water samples exceeding standard})}{\text{total population}}$$

3. Poor nutrition

   percentage of children below 5 years whose weight-for-age is less than the weight median - 2SD

4. Capacity of health services

   a) % = number of hospital beds, doctors and nurses per 1000 persons

   b) $\% = \frac{\text{population without health units}}{\text{total population in the province / city}} \times 100$

Linear transformation using the formula below was applied to each of the calculated values to obtain the respective index value. All the indicators were assigned equal weights and the HRI was computed by getting the average of the four indices.

$$\text{Index} = \frac{\text{Actual } X_i \text{ value} - \text{minimum } X_i \text{ value}}{\text{Maximum } X_i \text{ value} - \text{minimum } X_i \text{ value}}$$

Map to show patterns

The provinces / cities were classified into four categories depending on their computed index and assigned a color code. This information is then presented in a graphical format using thematic maps for each indicator and the overall composite index. These can be found in Figures 3.1 to 3.7.

Example of the HRI Methodology

The calculation of the provincial HRI is illustrated with two examples, Shanghai and Guizhou provinces.

1. Potential exposure to air pollution (indoor and outdoor air pollution)

   a) Indoor air pollution

$$\text{Shanghai} = \frac{\text{total amount of residential coal consumption}}{\text{total number of families}}$$

$$= \frac{1{,}549{,}700}{4{,}394{,}000} = 0.35$$

$$\text{Guizhou} = \frac{\text{total amount of residential coal consumption}}{\text{total number of families}}$$

$$= \frac{11{,}315{,}000}{8{,}595{,}200} = 1.32$$

The minimum and maximum values of residential coal consumption per household in China are 0 and 1.7 tons, respectively.

Indoor air pollution index:

$$\text{Shanghai} = \frac{0.35 - 0}{1.70 - 0} = 0.21$$

$$\text{Guizhou} = \frac{1.32 - 0}{1.70 - 0} = 0.77$$

b) Outdoor air pollution

$$\text{Shanghai} = \frac{\text{Urban population}}{\text{Total population}} \times 100$$

$$= \frac{1{,}184}{1{,}413.50} \times 100 = 83.76\%$$

$$\text{Guizhou} = \frac{\text{Urban population}}{\text{Total population}} \times 100$$

$$= \frac{793}{3{,}508.08} \times 100 = 22.60\%$$

The minimum and maximum values of potential exposure to outdoor air pollution in China are 0% and 83.76%, respectively.

Outdoor air pollution index:

$$\text{Shanghai} = \frac{83.76 - 0}{83.76 - 0} = 1.00$$

$$\text{Guizhou} = \frac{22.60 - 0}{83.76 - 0} = 0.27$$

Air pollution index:

$$\text{Shanghai} = \frac{0.21 + 1.00}{2} = 0.61$$

$$\text{Guizhou} = \frac{0.77 + 0.27}{2} = 0.55$$

2. Potential exposure to polluted water

$$\text{Shanghai} = \frac{1{,}184 \times 0.0288 + 229.5 \times 0.0358}{1413.50} \times 100 = 2.99\%$$

$$\text{Guizhou} = \frac{793 \times 0.1353 + 2715.1 \times 0.3469}{3508.08} \times 100 = 29.91\%$$

The minimum and maximum values of potential exposure to water pollution in China are 0.94 % and 81.50%, respectively.

Water pollution index:

$$\text{Shanghai} = \frac{2.99 - 0.94}{81.50 - 0.94} = 0.03$$

$$\text{Guizhou} = \frac{29.91 - 0.94}{81.50 - 0.94} = 0.36$$

3. Poor nutrition

The minimum and maximum values of poor nutrition in China are 0.24 % and 12.56 %, respectively.

Poor nutrition index:

$$\text{Shanghai} = \frac{0.24 - 0.24}{12.56 - 0.24} = 0.00$$

$$\text{Guizhou} = \frac{6.12 - 0.24}{12.56 - 0.24} = 0.48$$

4. Capacity of the health services

a) Population without access to health units:

The minimum and maximum values of population without access to health units in China are 0.49 % and 38.89 %, respectively.

Population without access to health units index:

$$\text{Shanghai} = \frac{0.49 - 0.49}{38.89 - 0.49} = 0.00$$

$$\text{Guizhou} = \frac{17.18 - 0.49}{38.89 - 0.49} = 0.43$$

b) Number of hospital beds, doctors and nurses per 1000 persons

The minimum and maximum values for the number of hospital beds, doctors and nurses per 1000 persons in China are 3.38 and 14.36, respectively.

$$\text{Shanghai} = 1 - \frac{11.81 - 3.38}{14.36 - 3.38} = 0.23$$

$$\text{Guizhou} = 1 - \frac{3.38 - 3.38}{14.36 - 3.38} = 1.00$$

Access to health services index:

$$\text{Shanghai} = \frac{0.00 + 0.23}{2} = 0.12$$

$$\text{Guizhou} = \frac{0.43 + 1.00}{2} = 0.72$$

5. Provincial HRI

The HRI is a simple average of the air pollution index, water pollution index, poor index and access to health service index.

$$\text{Shanghai} = \frac{0.61 + 0.03 + 0.00 + 0.12}{4} = 0.19$$

$$\text{Guizhou} = \frac{0.52 + 0.36 + 0.48 + 0.72}{4} = 0.52$$

Province	Air Pollution	Water Pollution	Poor Nutrition	Capacity of Health Services	HRI
Shanghai	0.61	0.03	0.00	0.12	0.19
Guizhou	0.52	0.36	0.48	0.72	0.52

Refinement of the health risk index for China

As in the work of UNDP and WRI, these preliminary indicators can be improved with additional data and time. This can serve as a starting point for future work. The data quality assurance was not included as part of the assessment. Initially, the HRI for China should be updated using the results of the 2000 population census. The following can be considered for future refinement:

a) Add another indicator such as human poverty index (HPI) per province

b) Consider endemic areas for vector-borne diseases

c) For indoor air pollution, consider biomass burning such as fuel wood in addition to coal burning for cooking

d) For malnutrition or poor nutrition, add daily per capita calorie supply and percentage of under 5 population at risk of micronutrient deficiency (iron and iodine)

e) Delphi approach - several experts and knowledgeable persons will be requested to classify each province / city as having low (1), moderate (2), or high (3) health risk potential. This will be collated and compared with the calculated index.

3.3 Patterns of Potential Health Risks from Environmental Threats

Most provinces in China face severe environmental threats to human health. Some of the poorer provinces experience high risks from indoor air polluted by the use of smoky fuels, but low risks from polluted outdoor air. Populations in other areas may face risks from both polluted indoor and outdoor air. Most of the provinces face a low to moderate potential for environmental health risks. Many of these provinces have expanded water and sanitation coverage in recent years.

Table 3.1 shows that Tianjin, Beijing and Shanghai top the list of cities having poor air quality. With increasing enhancement of urban air quality in these cities it is possible they will no longer be leading the list but would be found on the moderate scale. Table 3.2 shows that Tibet, Henan, and Yunnan provinces have severe water pollution, that is, they have no access to safe drinking water. Henan has the highest number of population exposed to unsafe drinking water especially in the rural areas. Table 3.3 shows that Ningxia, Yunnan, Tibet, Henan, and Guizhou have poor nutrition for children below 5 years old. Table 3.4 shows that Tibet, Zhejiang and Guizhou, have the least number of health units in the country, as well as scarce doctors and nurses. Table 3.6 provides the overall ranking for the whole country.

Next Steps

These preliminary indicators are a work in progress that can be improved with additional data. The final rankings for each country are suggestive, not definitive, and should be considered a starting point for exploring environmental health threats in greater detail. Although the best available data were used to construct the indicators, data were often incomplete or unreliable. Dividing the provinces into four risk categories is admittedly arbitrary. For instance, there may be little difference between countries at the cut-off points, that is, between high and medium risk or between medium and low risk. The broad categories, however, suggest differences in relative risks, and the indicator maps serve as preliminary tools for identifying provinces with significant health issues and different potential for exposure to environmental threats.

Table 3.2 Index of air pollution in China

	Indoor Air Pollution		Outdoor Air Pollution		
	Coal Consumption (Tons / Household)	**Index**	**Potential Exposure** (%)	**Index**	**Total Index**
Tianjin	1.10	0.65	69.86	0.83	0.74
Beijing	0.92	0.54	69.70	0.83	0.69
Shanghai	0.35	0.21	83.76	1.00	0.61
Tibet	1.70	1.00	13.39	0.16	0.58
Guizhou	1.32	0.77	22.60	0.27	0.52
Qinghai	1.17	0.69	28.26	0.34	0.51
Heilongjiang	0.55	0.32	46.49	0.55	0.44
Liaoning	0.41	0.24	52.13	0.62	0.43
Ningxia	0.74	0.43	28.86	0.34	0.39
Shanxi	0.62	0.36	29.80	0.36	0.36
Gansu	0.73	0.43	23.05	0.28	0.35
Jilin	0.21	0.12	46.83	0.56	0.34
Shandong	0.46	0.27	31.94	0.38	0.33
Inner Mongolia	0.31	0.18	38.24	0.46	0.32
Hubei	0.41	0.24	31.20	0.37	0.31
Xinjiang	0.36	0.21	32.64	0.39	0.30
Shaanxi	0.35	0.21	25.80	0.31	0.26
Hunan	0.39	0.23	23.00	0.27	0.25
Guangdong	0.06	0.03	39.27	0.47	0.25
Zhejiang	0.16	0.09	33.63	0.40	0.25
Sichuan	0.25	0.15	25.73	0.31	0.23
Jiangsu	0.22	0.13	27.31	0.33	0.23
Hebei	0.34	0.20	21.04	0.25	0.23
Henan	0.36	0.21	17.13	0.20	0.21
Jiangxi	0.21	0.13	22.61	0.27	0.20
Fujian	0.20	0.12	22.68	0.27	0.20
Anhui	0.23	0.14	19.19	0.23	0.18
Yunnan	0.24	0.14	16.39	0.20	0.17
Guangxi	0.11	0.07	18.44	0.22	0.15
Hainan	0.00	0.00	0.00	0.00	0.00

: no cities exceeding WHO guidelines
Source: National survey of 1% sampling population of China, 1995
According to China Environment Yearbook 1999

Table 3.3 Index of water pollution in China

	Population Without Safe Water		Population Exposed to Unsafe Water	Index
	Urban (10,000)	Rural (10,000)		
Tibet	18.23	176.47	81.50	1.00
Henan	275.01	4712.44	54.81	0.67
Yunnan	142.24	1204.28	33.91	0.41
Ningxia	31.36	124.51	30.60	0.37
Guizhou	107.31	941.98	29.91	0.36
Gansu	88.74	640.20	29.90	0.36
Guangxi	164.28	1182.95	29.76	0.36
Zhejiang	236.95	1032.77	29.45	0.35
Shaanxi	129.61	754.98	25.28	0.30
Heilongjiang	211.50	674.64	23.99	0.29
Shanxi	84.26	588.56	21.86	0.26
Anhui	164.02	1146.20	21.79	0.26
Liaoning	127.08	654.56	19.13	0.23
Sichuan	388.77	1657.86	18.14	0.21
Shandong	709.32	833.16	17.75	0.21
Jiangxi	97.53	602.29	17.29	0.20
Hainan	52.40	68.22	16.66	0.20
Fujian	22.76	490.93	15.91	0.19
Inner Mongolia	206.97	153.16	15.81	0.18
Hubei	307.44	556.14	15.00	0.17
Jiangsu*	112.90	897.37	14.32	0.17
Xinjiang	47.34	174.16	13.39	0.15
Guangdong*	223.50	654.42	12.84	0.15
Beijing	71.36	89.01	12.82	0.15
Hunan	147.11	504.95	10.21	0.12
Jilin	96.95	153.32	9.67	0.11
Tianjin	5.84	59.63	6.96	0.07
Hebei	43.79	385.48	6.67	0.07
Shanghai	34.08	8.23	2.99	0.03
Qinghai	4.51	0.00	0.94	0.00

Source: Annual report on health statistics, MOH, 1999
*Annual report on health statistics, MOH, 1998

Table 3.4 Poor nutrition of children under 5 years in China

	Poor Nutrition (%)	Index
Ningxia	12.56	1.00
Yunnan	7.97	0.63
Tibet	6.28	0.49
Henan	6.17	0.48
Guizhou	6.12	0.48
Qinghai	5.84	0.45
Gansu	5.69	0.44
Jiangxi	5.21	0.40
Guangxi	4.97	0.38
Hainan	4.69	0.36
Jilin	4.63	0.36
Shanxi	4.11	0.31
Hebei	3.71	0.28
Shaanxi	3.20	0.24
Xinjiang	2.78	0.21
Anhui	2.75	0.20
Sichuan	2.73	0.20
Fujian	2.70	0.20
Hunan	2.66	0.20
Inner Mongolia	2.64	0.19
Hubei	2.60	0.19
Guangdong	2.25	0.16
Liaoning	1.87	0.13
Shandong	1.78	0.13
Zhejiang	1.55	0.11
Jiangsu	1.51	0.10
Heilongjiang	1.36	0.09
Tianjin	0.79	0.04
Beijing	0.61	0.03
Shanghai	0.24	0.00

Source: Annual report on health statistics, MOH, 1999

Table 3.5 Access to health services in China

	Without Health Units		Health Care		Total Index
	Population Without Health Unit (%)	Index	Hospital Beds Doctors / Nurses (per 1000)	Index	
Tibet	38.89	1.00	5.36	0.82	0.91
Zhejiang	25.55	0.65	4.78	0.87	0.76
Guizhou	17.18	0.43	3.38	1.00	0.72
Sichuan	11.51	0.29	4.27	0.92	0.60
Hainan	13.46	0.34	5.84	0.78	0.56
Anhui	4.61	0.11	3.60	0.98	0.54
Shaanxi	10.02	0.25	5.34	0.82	0.53
Hunan	6.16	0.15	4.34	0.91	0.53
Hubei	8.26	0.20	5.17	0.84	0.52
Gansu	6.16	0.15	4.62	0.89	0.52
Henan	2.07	0.04	3.71	0.97	0.51
Jiangxi	3.71	0.08	4.21	0.92	0.50
Guangdong	5.16	0.12	4.63	0.89	0.50
Guangxi	2.37	0.05	3.90	0.95	0.50
Shandong	4.97	0.12	4.69	0.88	0.50
Hebei	4.34	0.10	4.55	0.89	0.50
Fujian	2.71	0.06	4.65	0.88	0.47
Jiangsu	3.42	0.08	4.97	0.86	0.47
Ningxia	5.55	0.13	5.63	0.80	0.46
Yunnan	1.09	0.02	4.51	0.90	0.46
Inner Mongolia	4.45	0.10	6.11	0.75	0.43
Shanxi	6.95	0.17	6.86	0.68	0.43
Xinjiang	8.69	0.21	8.06	0.57	0.39
Heilongjiang	2.68	0.06	6.63	0.70	0.38
Qinghai	2.87	0.06	6.91	0.68	0.37
Jilin	3.30	0.07	7.17	0.65	0.36
Liaoning	1.20	0.02	8.56	0.53	0.27
Tianjin	2.29	0.05	10.05	0.39	0.22
Shanghai	0.49	0.00	11.81	0.23	0.12
Beijing	5.27	0.12	14.36	0.00	0.06

Source: Annual report on health statistics, MOH, 1999

Table 3.6 Overall health risk index for China

	Health Risk Index				Total Health Risk Index
	Air Pollution	Water Pollution	Poor Nutrition	Access to Health Service	
Tibet	0.58	1.00	0.49	0.91	0.75
Ningxia	0.39	0.37	1.00	0.46	0.56
Guizhou	0.52	0.36	0.48	0.72	0.52
Henan	0.21	0.67	0.48	0.51	0.47
Gansu	0.35	0.36	0.44	0.52	0.42
Yunnan	0.17	0.41	0.63	0.46	0.42
Zhejiang	0.25	0.35	0.11	0.76	0.37
Guangxi	0.15	0.36	0.38	0.50	0.35
Shanxi	0.36	0.26	0.31	0.43	0.34
Qinghai	0.51	0.00	0.45	0.37	0.33
Shaanxi	0.26	0.30	0.24	0.53	0.33
Jiangxi	0.20	0.20	0.40	0.50	0.33
Sichuan	0.23	0.21	0.20	0.60	0.31
Heilongjiang	0.44	0.29	0.09	0.38	0.30
Hubei	0.31	0.17	0.19	0.52	0.30
Anhui	0.18	0.26	0.20	0.54	0.30
Jilin	0.34	0.11	0.36	0.36	0.29
Shandong	0.33	0.21	0.13	0.50	0.29
Hainan	0.00	0.20	0.36	0.56	0.28
Inner Mongolia	0.32	0.18	0.19	0.43	0.28
Hunan	0.25	0.12	0.20	0.53	0.28
Hebei	0.23	0.07	0.28	0.50	0.27
Tianjin	0.74	0.07	0.04	0.22	0.27
Fujian	0.20	0.19	0.20	0.47	0.27
Guangdong	0.25	0.15	0.16	0.50	0.27
Liaoning	0.43	0.23	0.13	0.27	0.27
Xinjiang	0.30	0.15	0.21	0.39	0.26
Jiangsu	0.23	0.17	0.10	0.47	0.24
Beijing	0.69	0.15	0.03	0.06	0.23
Shanghai	0.61	0.03	0.00	0.12	0.19

A more focus table is shown in Table 3.7 which shows the top 5 provinces with the highest health risk as well as the last 5 provinces/cities with the least health risk. If one will analyze the case of each province belonging to the top 5, it is obvious from the table that Tibet has a water pollution problem as well as inadequate health care facilities. However, Table 3.2 reveals that Tibet has the worst case of indoor air pollution since they continue to use coal for cooking and heating but the outdoor air quality is very good since there is limited development in the province. Shanghai's poor outdoor air quality is from motor vehicles, industries and power plants but the indoor air quality is good since they use gas for cooking. Guizhou's main concern is its poor health care facilities (Table 3.5) while Henan has unsafe drinking water (Table 3.3). On one hand, Ningxia's main problem is its poor nutrition since it has the highest percentage of malnourished children under 5 years old (Table 3.4). Ganzu, on one hand, has an equal share of all the problems. These tables can aid in putting priorities in health and environmental improvements per province.

Table 3.7 Top 5 and bottom 5 provinces with respect to health risk

	Air Pollution	Water pollution	Poor nutrition	Access to health service	Health Risk Index
1.Tibet	0.58	1.00	0.49	0.91	0.75
2. Ningxia	0.39	0.37	1.00	0.46	0.56
3. Guizhou	0.52	0.36	0.48	0.72	0.52
4. Henan	0.21	0.67	0.48	0.51	0.47
5. Gansu	0.35	0.36	0.44	0.52	0.42
26. Liaoning	0.43	0.23	0.13	0.27	0.27
27. Xinjiang	0.30	0.15	0.21	0.39	0.26
28. Jiangsu	0.23	0.17	0.10	0.47	0.24
29. Beijing	0.69	0.15	0.03	0.06	0.23
30. Shanghai	0.61	0.03	0.00	0.12	0.19

In Figure 3.1, the whole country has been classified into four categories based on their health risk index. To rank them is rather difficult to do since index value for some of the provinces is only slightly different and the distinction from low to moderate as well as from moderate to high is not significant. Nevertheless, it will give an indication of the health of each province on a macro level but still not quite sensitive.

To best appreciate the data in the preceding tables, the results were put in various thematic maps to highlight the provinces / cities that have the highest or lowest health risks. The whole country was classified into four categories based on their health risk index. To rank them is rather difficult to do since index value for some of the provinces is only slightly different and the distinction from one category to another is sometimes not significant. Nevertheless, it will give an indication of the health status of each province on a macro level but still not sensitive enough due to limited indicators.

The four levels are: 0-0.25 (green), 0.26-0.50 (blue), 0.51-0.75 (yellow) and 0.76-1.00 (red). The red color symbolizes the province with the highest health risk index. With this classification, the variation in each province can be easily detected from the maps.

In Figure 3.1, Tibet, Ningxia and Guizhou came out to be the top provinces with the highest overall health risk index. This indicates that these provinces require more attention in terms of addressing their pollution and health problems. The last three are in green (Beijing, Jiangsu and Shanghai). This means that the quality of life in these three places is much higher than the rest of the country.

Figure 3.2 shows the combined indoor and outdoor air pollution index throughout the country. From the map, six places can be found to have air pollution issues (Tibet, Qinhai, Guizhou, Shanghai, Tianjin and Beijing). However, in Figure 3.3, which depicts indoor air pollution situation in the country, only Tibet and Guizhou appeared to have significant problem, followed by Qinghai, Beijing and Tianjin. In Figure 3.4 on outdoor air pollution, Beijing, Shanghai and Tianjin are the top three places with this problem, presumably due to massive coal burning and more motor vehicles. The northern provinces of Heilonjiang, Jilin, and Liaoning were also found to have outdoor air pollution problem.

Figure 3.5 depicts the drinking water situation in the country. From this map, Tibet is found to have serious drinking water situation since more than 80% of its population are exposed to unsafe drinking water. More than 50% of the population of Henan do not have safe drinking water.

The nutritional status of the country is presented in Figure 3.6. Ningxia tops the list since around 12% of its children under 5 years old are malnourished. Yunnan province also has an incipient nutrition problem that needs to be addressed.

Finally, Figure 3.7 gives a picture of the health services in the country. Tibet and Zhejiang were found to have fewer resources in terms of health care facilities and health workers. On the other hand, Beijing, Tianjin and Shanghai are shown to have the best medical services in the country.

Figure 3.1 - Potential Risk to Human Health in China, 2001

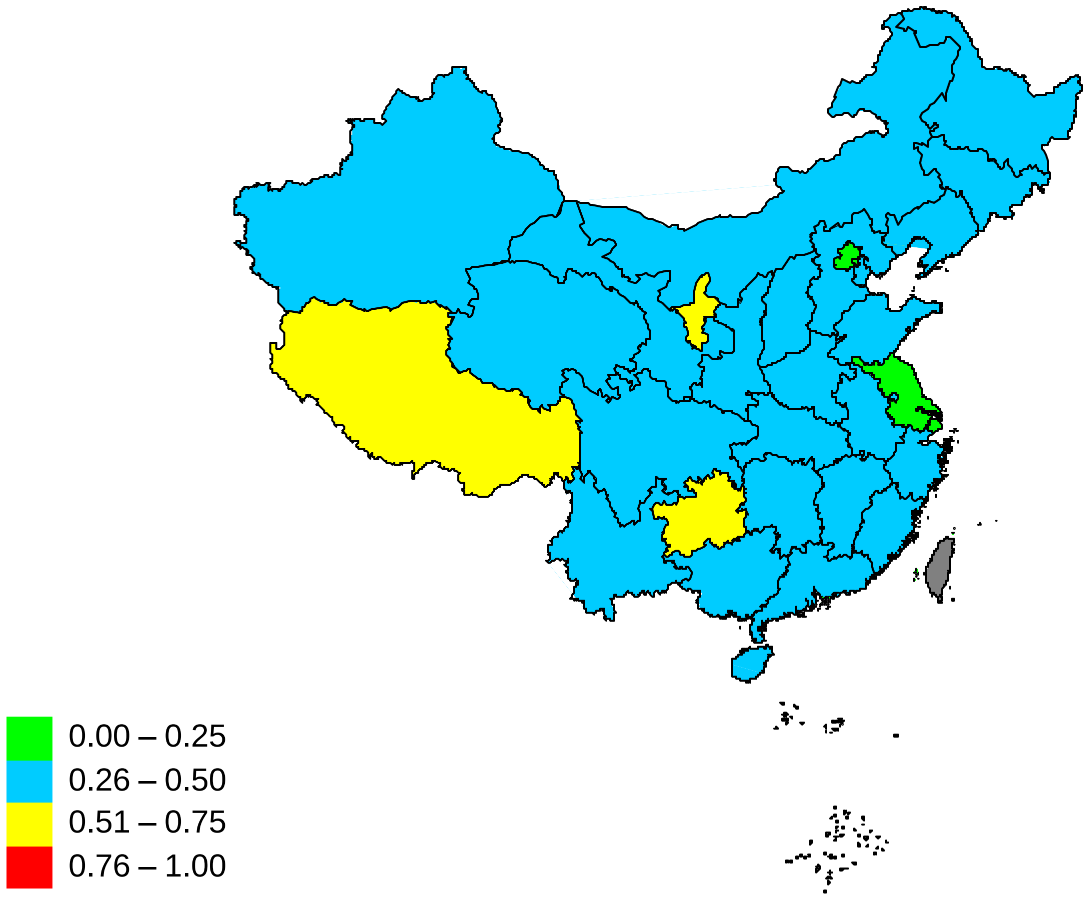


Figure 3.2 – Combined air pollution index in China

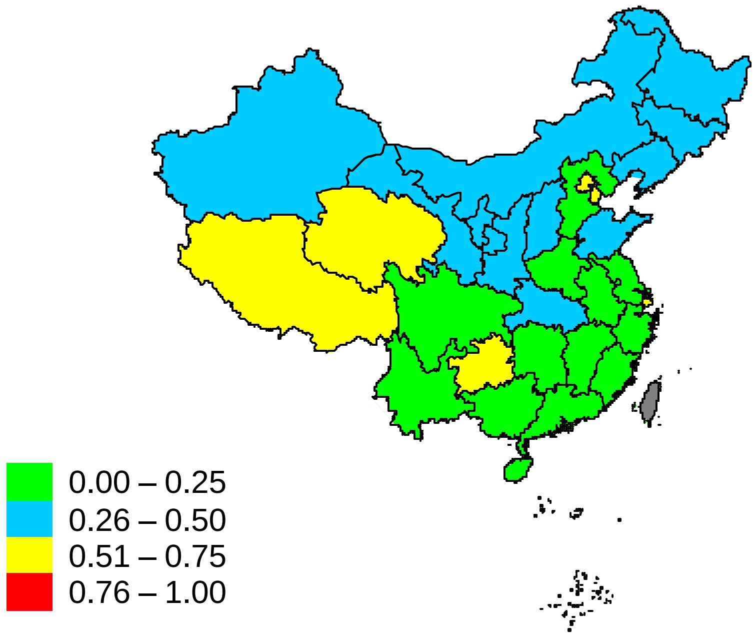


Figure 3.3 – Indoor air pollution index in China

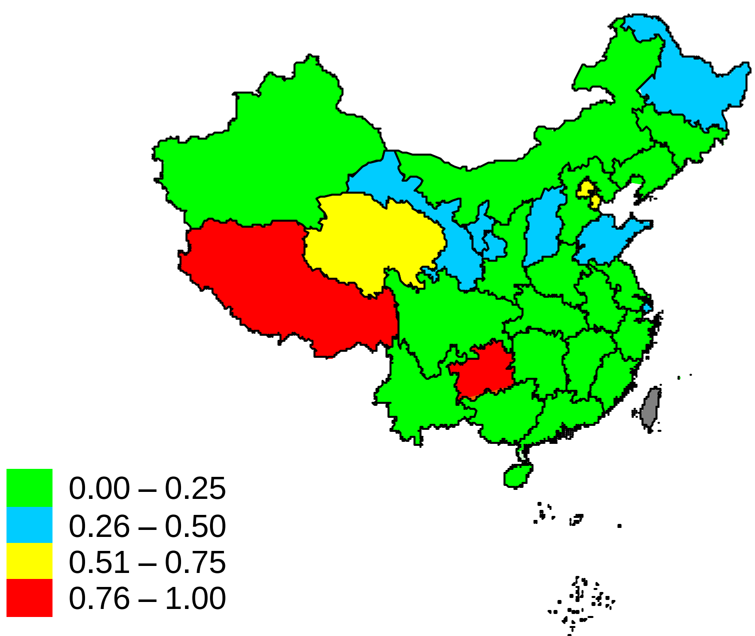


Figure 3.4 – Outdoor air pollution index in China

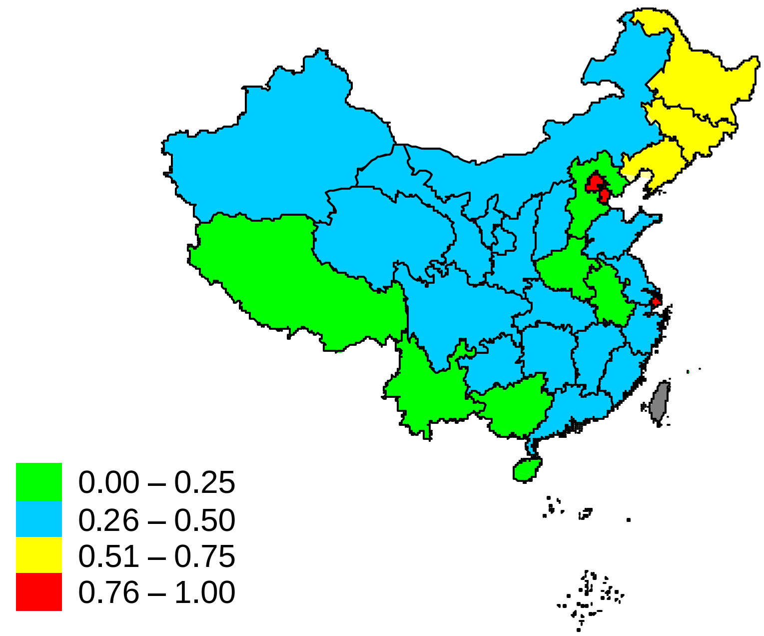


Figure 3.5 - Drinking water pollution index in China

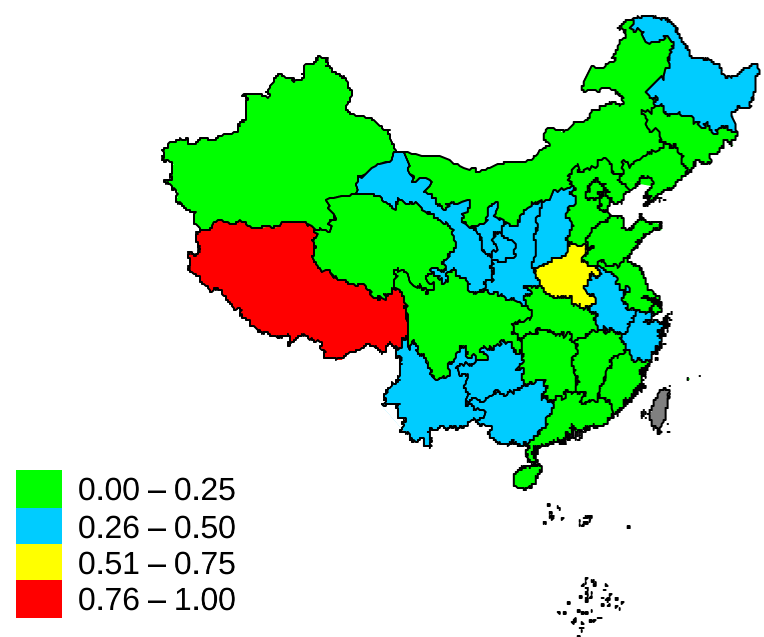


Figure 3.6 - Malnutrition index in China

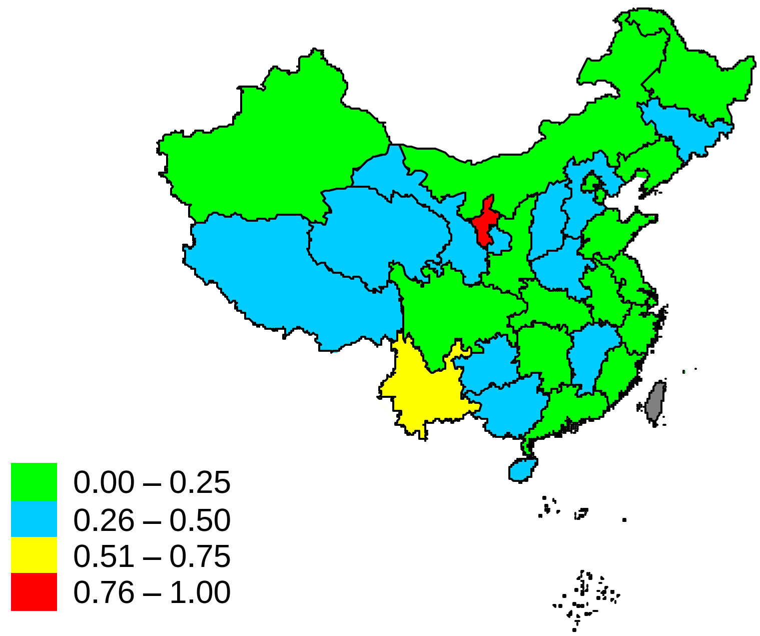
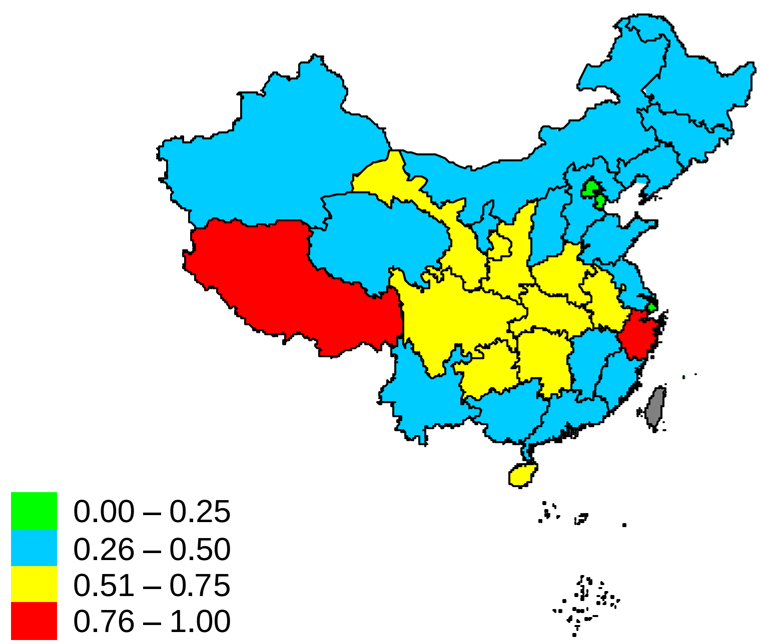


Figure 3.7 – Health services index in China



Chapter 4

Advisory Note: Recommendations for Action

There is a strong link between increased mortality and morbidity due to environmental pollution in China. Monitoring sites of environmental quality of both air and water are not adequate and data quality assurance is not generally practised. Information on TVEs and their health impacts are limited. There are several priority activities on environmental protection and health that can be undertaken jointly by Chinese and international agencies. Based on the calculated health risk index, the health impacts due to environmental pollution are increasing and measures should be done to address them. There is not enough trained manpower in China on risk assessment and management. Technical assistance is required on control of environmental pollution and policy development for stronger environmental health.

General recommendations

Based on the findings and results of the study on Environment and People's Health in China, the following general recommendations are proposed:

a) Guidelines for environmental health impact and risk assessment should be developed as well as provide capacity for enforcement.
b) More air quality monitoring stations should be established close to the Disease Surveillance Points.
c) Drinking water quality monitoring and surveillance should be done more frequently and effectively.
d) More environmental controls and cleaner production measures should be introduced to the town and village enterprises (TVEs) along with occupational health and safety considerations.
e) The health risk index for China should be used and refined using more indicators and variables with recent data and with data quality assurance.
f) Collaborative project proposals such as arsenic intervention and control, lake microcystin removal, cleaner coal and air quality improvement should be implemented as soon as possible.
g) Further work between UNDP, WHO, and the Chinese government on environment and people's health should be continued.

Specific recommendations

Based on the findings and results of the study on Environment and People's Health in China, the following specific recommendations are proposed:

a) Global warming issues and health should be investigated especially on vulnerability of patients to extreme heat waves during summer, made worse by air pollution.
b) Long-range reduction of coal consumption should be emphasized in both industries and households.

c) With respect to particulate matters, PM_{10} and $PM_{2.5}$ should be monitored and their correlation with SO_2 concentration and mortality should be studied.
d) A separate analysis for rural, urban and urban central areas is essential to establish combined mortality risks of outdoor SO_2 and indoor coal-burning pollution.
e) Ambient SO_2 level in China should be regarded as a representative index of a complex variety of pollutants in relation to both morbidity and mortality risks.
f) It is important to convert health risks to economic losses or other economical indicators through the willingness-to-pay methods, whose feasibility has not yet been demonstrated in China.
g) Ecological correlation-based mortality risk analyses should be applied to drinking water pollution as well as TVEs pollution, as suggested by epidemiological studies.
h) Similar mortality risk analyses should be applied to possible inorganic chemical pollution such as arsenic, selenium, mercury, and fluoride from natural sources and TVEs.
i) Organic pollution from dioxin, polychlorinated biphenyls, and agricultural chemicals should be studied especially in relation to cancer such as breast cancer and congenital anomalies.
j) Future studies in specific areas such as drinking water contaminated with arsenic, fluoride and microcystins in Nanjing, Jiangsu province and air pollution and respiratory diseases in Taiyuan, Shanxi province. The objectives of the follow-up study are to:

- Investigate the quality of DSP data in more detail.
- Check the correlation of TSP, PM_{10} and $PM_{2.5}$ in relation to SO_2 and NO_2 across the 28 DSP cities.
- Obtain indoor coal consumption data classified by rural and urban areas in the two provinces.
- Develop indices of water pollution and TVEs pollution for further analyses of the DSP data including mortality from various cancers.
- Obtain preliminary information regarding the body burden of chemicals including dioxins, PCBs, and other POPs as well as toxic elements such as As, F, Pb, and Cd from human samples such as human milk, blood, and urine.
- Determine the risk awareness and perception among the public through, for example, the willingness-to-pay method and human capital approach.

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