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ACIDIC DEPOSITION AND ITS CONTROL COUNTERMEASURES IN CHINA

Kai-Qin Xu[1]
Wenxing Wang[2]
Ryuichi Sudo[3]

Abstract

Acidic deposition has become a major worldwide environmental problem, and the effect of acidic deposition has been noticeable through dying forests, increasing acidity of lakes and reservoirs, and the destruction of outdoor sculptures and buildings. It often causes problems beyond the borders because the acidic pollutants may fall several thousand kilometers away from the emission sources. It is necessary to establish what the current situation is in these areas. The objective of this paper is to describe the present state and trends of acidic deposition and its countermeasures in China. Nationwide research projects, major research fields involved, the control policy, and mitigate measures are also discussed in this paper. The results show that the acidic deposition mainly occurs in the south of Yzangtze (Chang Jiang) River, and limited acidic deposition was recorded in northern and eastern China. Local pollution is the major reason for acidic deposition, whereas long range transport plays a relatively minor role. The area affected by acidic deposition accounts for about 6.8 % of the total area of the state, and the area with serious problems account for 11.7 % of the total area affected by acidic deposition. The problem of acidic deposition shows a tendency that it is more serious in the southern area than in the northern area. The pH of precipitation in fall and winter is usually lower than that in spring and summer. SO_4^{2-} is the major reason for acidic deposition in China. A significant relationship exists between pH and atmospheric concentration of SO_4^{2-} and concentration of particle material. Various countermeasures have been or will be made to control acidic deposition in China.

KEYWORDS: *Acidic deposition, China, Nitrogen oxides, pH, Sulfur oxides*

1. Introduction

Acidic pollutants fall on the surface of the earth in the form of acid rain and cause adverse effects. Acid rain often causes problems beyond the borders because it sometimes falls several thousand kilometers away from the emission sources. Actually, acidic deposition began to attract attention as a regional scale environmental problem during 1970s in the northeastern part of the United States, southeastern Canada, southwestern Scotland, and parts of the Scandinavian countries. Damages caused by acid rain to soil, forests, lakes, and buildings have been reported.

1 Dr. Eng., Research Associate, Department of Civil Engineering, Tohoku University, Aoba, Sendai 980-77, Japan.
2 Dr. Sci., Professor, Chinese Research Academy of Environmental Sciences, Beiyuan, Beijing 100012, China.
3 Dr. Sci., Professor, Department of Civil Engineering, Tohoku University, Aoba, Sendai 980-77, Japan.

Acid rain has the most direct impact on lakes, reservoirs, and rivers. A number of lakes have been acidified in the northeastern part of the United States, southeastern Canada, southwestern Scotland, and parts of the Scandinavian countries. Damage on aquatic life is in evidence in 2,500 Swedish lakes which have been affected by acid rain believed attributable to sulfur oxides and nitrogen oxides mainly from the central industrial belt in Europe. Damage is expected to 6,500 other lakes in that country (Sudo and Xu, 1993).

Damages caused by acid rain to soil, forests, and buildings in Sweden have also been reported. As for effects on human health, there is concern over the possibility that metals dissolved from bronze pipes resulting from the acidification of the sources of drinking water or those dissolved into the environment by the acidification of soil may find their way into the body through the food chain.

More recently attention has been paid to acidic deposition in northeastern Asia. In China about 18 million tons sulfur oxides and 7.5 million tons nitrogen compounds are expected to be released annually to the atmosphere, because coal is the predominant source of energy. The main part of this enormous amount of pollutants deposits within its own territories. However, the possibility for the pollutants to be carried over to Korea and Japan is quite high, especially in the winter season. The energy demand and the development of industrial activities in China are expected to grow more rapidly in the near future. However, studies on the regional environment in China have just started. In many developing countries, SO_2 has been released from coal combustors without SO_2 abatement process. Therefore, serious effects of acidic precipitation have been recognized in China, particularly in the new southwestern industrial regions which are now exploiting extensive coal deposits of high sulfur content. To evaluate the effects of the acidic deposition on the terrestrial and aquatic ecosystems, it is important to accumulate fundamental data on precipitation chemistry, such as SO_2, NO_x, TSP, cation and anion component, in these areas (Wang *et al.*, 1993, 1993a).

Considerable research has been performed and hundreds of scientific papers and several major books and reports have been written on the subject. We now have a good understanding of the nature and extent of at least wet acidic deposition, and we know that current low pH values for a wet fall are caused primarily by sulfur and nitrogen oxide emission from combustion of fossil fuels. The most important contributions are the assessment of the significance of these variations to our understanding of the acidic deposition phenomenon and its implications for public policy decisions (Charles, 1991).

In order to resolve the mechanisms of formation of acidic deposition and define effective countermeasures for the future, it is necessary to establish what the current situation is in these areas. The objective of this study is to describe the present state and trends of acidic deposition and its countermeasures in China. Nationwide research projects, major research fields involved, the control policy, and mitigate measures are also discussed in this paper.

2. A Brief History of Nationwide Studies on Acidic Deposition

Almost 90% of the population in China was living in rural areas around 1950, and people were enjoying a life mainly based on agricultural cultivation. Meanwhile, the industrial production level in the cities was very low, and there were almost no air pollution and acidic precipitation problems. Later on, the Chinese government implemented plans for the development of the national economy based on the development of the industrial production. Since the national economy and industry developed especially during the period starting from late

Table 1. Key projects of state's seventh five-year plan (1985–1990).

Topics No.	Contents
1	Acidic Deposition at the State Level
2	Acidic Deposition in Southwestern China and Its Ecological Effect
3	Acidic Deposition in Southern China
4	Acidic Deposition in Ermei Mountain Area Its Source and Transport
5	Ecological Effect Attributed to Acidic Deposition.

1970s, China has been one of the most observed countries in the world, because of the rapid economic and social development. During this period, the growth of various industries, energy consumption, transportation, and population led to a large energy demand. The combustion of fossil fuel, such as coal, oil, and natural gas, has increased air pollutant emissions (Quan, 1993; Cheng, 1993).

Study on the acidic deposition in China was initiated in the Sichuan province (located in southwestern China), and monitoring was occasionally carried out before 1982. After 1982 , the Environmental Protection Agency (EPA) of the State Council issued a national monitoring project with the purpose of getting an overview of the acidic deposition in China (Zhao, 1988).

A nationwide project on acidic deposition started in 1985 entitled "Source of Acidic Deposition in China and the Policy of Control". This was supported by the State Planning Committee and was chaired by the Chinese EPA. The project included five sub-projects as outlined in Table 1.

Results of the sub-projects showed that acidic deposition mainly appeared in some areas of southwest and southern China. In some regions the problem is even more serious and economic loss was recorded. This arose the deep concern of the state government and an investment of 5.5 million Yuan (RMB) was afforded to continue the study, especially focussing on southwestern and southern China. This directly led to a project entitled "Study on the Acid Rain", one of the key projects of the state's seventh five-year plan (from 1985-1990). The project was composed of two sub-projects including "Study on the Acid Rain in Southwestern China" and "Study on the Acid Rain in Southern China." Both sub-projects included five topics as listed below (Wang, 1993, 1993a, 1993b; Xu *et al.*, 1994).

(1) The present status of acid rain in the project area;
(2) The transport of acidic pollutants;
(3) The chemical procedure of acidic deposition;
(4) The ecological effect of acidic deposition;
(5) The controlling policy of acidic deposition

With the completion of these two sub-projects, China primarily got the results of the monthly and annual distribution, dynamics and trends of the acidic deposition on a nationwide scale. Meanwhile, in some areas with serious problems of acidic deposition, the studies on the source of acidic pollutants, transport and ecological effects were also emphasized. The same survey was also carried out in the central and eastern China. In 1990-1995 an inter-discipline and inter-ministry research networks were established.

3. Major Research Fields

Besides the nationwide research projects, many other topics are also under study. Three major fields include:

1) Distribution, dynamics and trends of acidic deposition

In this field, studies include geological and vertical distribution dynamics and trends of variation of pH and related chemical components, atmospheric background of precipitation, the relationship between acidity and other chemical, physical, geological, and meteorological factors, and the relationship between acidic deposition and air pollutants. Monitoring plays an indispensable role in the studies of acidic deposition. After 1982, more than 300 monitoring stations and about 900 field points were established in 26 provinces and autonomous regions all over the country except in Xinjiang, Tibet, and Taiwan. Figure 1 shows the distribution of monitoring stations of acid rain in China. The main objective of the acidic precipitation monitoring network is to measure the concentrations of the components in the precipitation, depending on guidelines which were published by the National Environmental Protection Agency. The analyzed parameters and methods used are shown in Table 2.

In 1986, after several years of research, the "State Standard Methods for Monitoring and Analysis of Chemical Components in Precipitation" was published. It set up rules concerning the location of field points, sample collection and transport, monitoring and analytical instruments, and standard methods for laboratory analysis. Quality control and assurance systems were established and regular assessment of the work at monitoring stations was conducted.

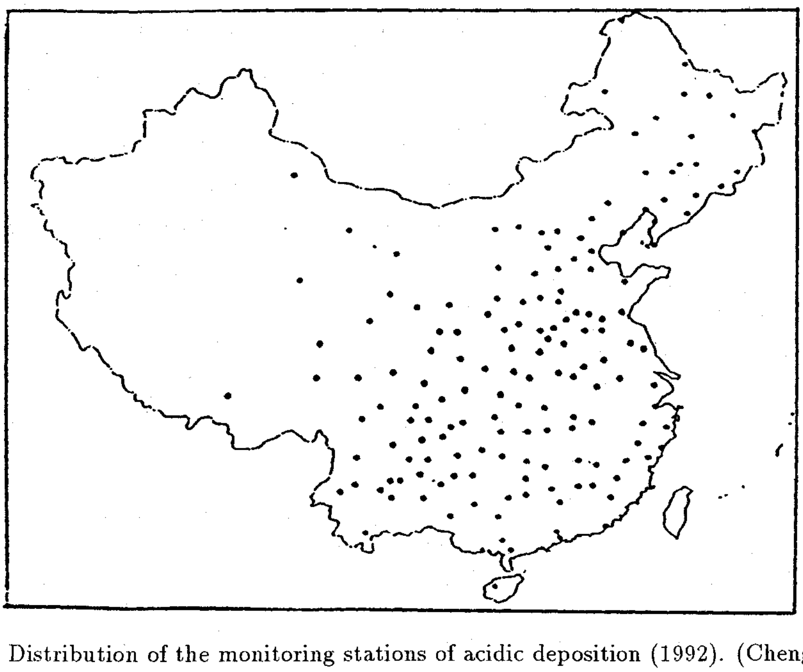

Figure 1. Distribution of the monitoring stations of acidic deposition (1992). (Cheng, 1993)

Table 2. Parameters and methods used in analysis of precipitation samples.

Parameters	Analytical Method
pH	Glass electrode pH meter
EC	Electrical conductivity detector
SO_4^{2-}	Turbidimetry of Barium sulfate method Turbidimetry of improved Barium sulfate method Barium chromate/diphenylcarbazite method Ion chromatography
NO_3^-	Reduction by Cadmium/N-(-naphthyl) ethylene diamine method Ultraviolet spectrometry Ion chromatography
NH_4^+	Nessler's reagent method Sodium hypochlorite salicylic acid method
Cl^-	Mercury thiocyanate method Ion chromatography
Ca_2^+	Atomic absorption spectrophotometry Colorimetric method by chlorophosphonazo III Chelatometric titration (EDTA)
Na^+, K^+, Mg^{2+}	Atomic absorption spectrophotometry

2) Physical and chemical procedures

Research topics in this field cover influence factors for the precipitation's acidity; formation of acidic deposition; relationship between acidic deposition and meteorological systems; and sources of acidic pollutants, its transport and statistic modelling.

3) Ecological effects and economic loss

Ecological effects attributed to acidic deposition can be found on terrestrial and aquatic ecosystems and construction material. Studies in this field include:

(1) modelling experiment of acidic deposition on plants;
(2) analysis of the relationship between acidic deposition and forestry damage;
(3) effect of acidic deposition on plankton and fish community;
(4) sensitivity of soil to acidic deposition;
(5) mechanism of erosion of acidic deposition on constructing material.

Several nationwide projects on acidic deposition disclosed serious effects on the environment. This research field will be more and more important in the study of acidic deposition.

4. The Present Status of Acidic Deposition

Several nationwide projects have identified the status of acidic deposition in China. The results show that the acidic deposition is mainly distributed in the south of Yangtze River, especially in four regions including (1) Sichuan Basin; (2) Guizhou Province; (3) Hunan, Hubei, and Jiangxi provinces; (4) Coastal provinces of Fujian, Guangdong. Limited acidic deposition is recorded in northern and eastern China. Local pollution is the major reason for acidic

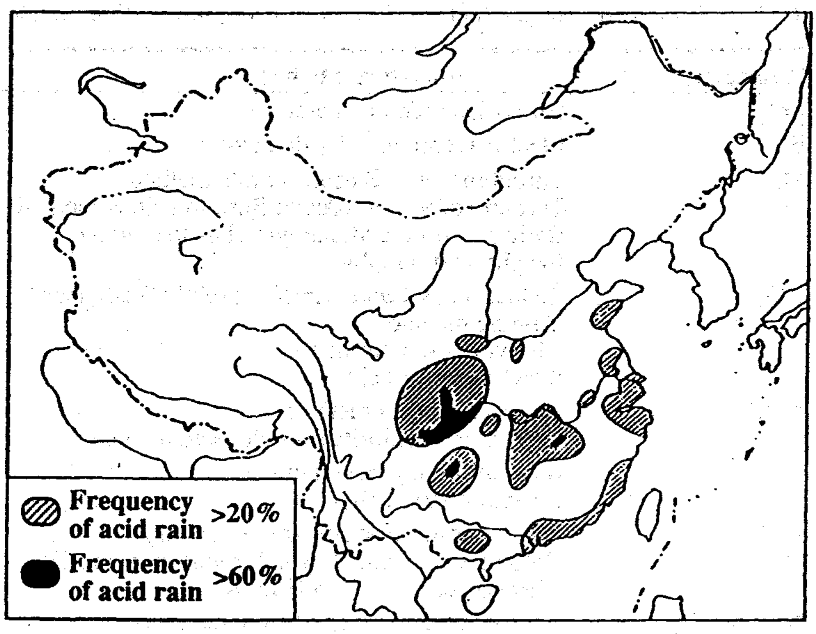

Figure 2. Frequency distribution of acid precipitation in China (1985–1990). (Quan, 1993)

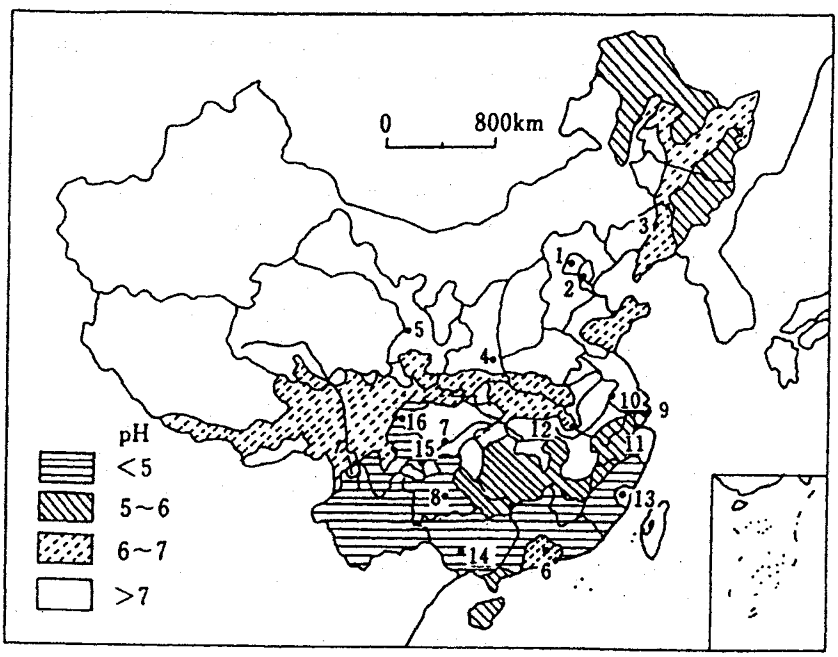

Figure 3. Distribution of the pH values in the soil (1985–1990). (Zhao, 1988) [1: Beijing, 2: Tianjin, 3: Shenyang, 4: Xian, 5: Lanzhou, 6: Guangzhou, 7: Chongqing, 8: Guiyang, 9: Shanghai, 10: Nanjing, 11: Hanhzhou, 12: Wuhan, 13: Fuzhou, 14: Nanning, 15: Yibing, 16: Chengdu]

Table 3. The main chemical components of precipitation in northern and southern cities. (unit: μeq/l)

	stations	Samplers	SO_4^{2-}	NO_3^-	NH_4^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}/NO_3^-	pH
North	Beijing	28	154.5	39.5	162.8	151.6	12.1	3.91	6.90
	Changchun	34	156.5	21.2	61.3	256.5	51.2	7.38	6.71
	Shenyang	19	398.0	50.3	99.0	305.4	395.3	7.96	6.41
	Xian	5	358.1	67.3	275.8	1795.4	66.84	5.32	7.15
	Yantai	2	182.5	22.8	39.1	289.1	20.1	8.00	6.97
South	Chongqing	21	326.6	27.9	151.1	127.8	31.5	11.7	4.21
	Guiyang	4	405.2	27.9	174.3	199.6	65.2	14.5	4.23
	Nanning	29	61.6	4.9	27.7	26.6	1.4	12.6	4.82
	Shanghai	36	153.4	12.6	75.8	104.3	27.9	12.2	4.85
	Hefei	42	141.9	31.8	117.3	110.3	13.7	4.46	4.73

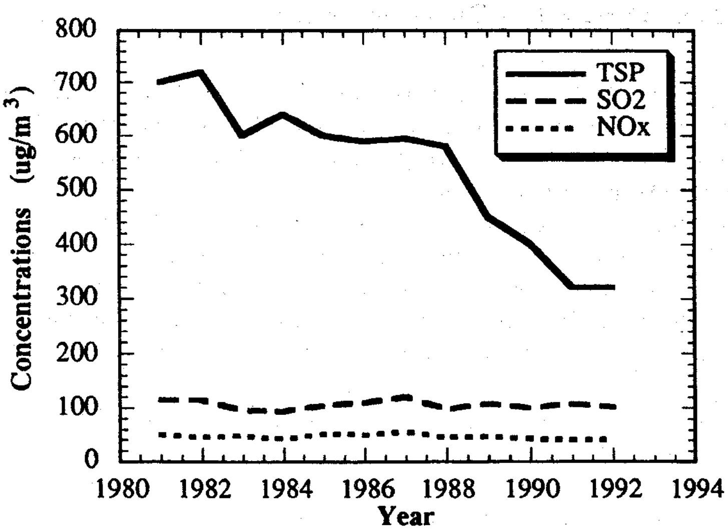

Figure 4. Annual trends of average TSP, SO_2, and NO_x concentrations in China. (Cheng, 1993)

deposition, whereas long range transport plays a relatively minor role. The area affected by acidic deposition accounts for about 6.8 % of the total area of the state and the area with serious problems accounts for 11.7 % of the total area affected by acidic deposition. Figure 2 shows the frequency distribution of acidic deposition in China from 1985 to 1990.

Acidic deposition shows a tendency that is more serious in the southern areas than in the northern areas. This is partly because the pH of soil in northern China ranges from 7-8, whereas in southern China the pH ranges from 5-6. Figure 3 shows the distribution of the pH values for the soils in China. The chemical components of precipitation are also much different in the southern and northern areas (Table 3). The components of NH_4^+ and alkali metal were higher in the northern than in the southern area.

Figure 4 shows the trends of the average TSP, SO_2 and NO_x concentrations from 1981 to 1992. The concentration of total suspended particles (TSP) in cities has decreased greatly, both in southern and northern cities, in the past decade due to effective control of smoke dust for coal burning. For example, TSP annual average concentration was 700μg/m^3 in 1981 and

Table 4. Ambient air quality standards in China.

Items	Limited Concentration (mg/m^3) Grade 1	Grade 2	Grade 3	Remarks
TSP	0.15	0.30	0.50	day average
	0.30	1.00	1.50	anytime
SO_2	0.02	0.06	0.10	day average
	0.05	0.15	0.25	anytime
NO_x	0.05	0.10	0.15	day average
	0.10	0.15	0.30	anytime
CO	4.00	4.00	6.00	day average
	10.00	10.00	20.00	anytime
O_3	0.12	0.16	0.20	hour average

Source: Chinese National Standard GB3095-82

dropped to $320\mu g/m^3$ in 1992. Southern cities have TSP annual average concentrations lower than national standards, but in northern cities it is still higher than the standards (Table 4). The trends of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) concentrations in cities have not changed significantly (Wang *et al.*, 1993).

Major cities in China where TSP concentration exceeded the national standard grade 3 are mainly located in lower stretches of Yellow River–that is the middle eastern region of China. In this region, a vast amount of coal is being used for heating in winter, and the area is also very dry due to shortage of rain. In contrast, TSP concentrations in the region south of Yangtzu River (Chang Jiang) are quite low as a result of a lot of rain (Wang *et al*, 1993; Xu *et al.*, 1994).

The distribution of the concentration of SO_2 in the major cities in 1992 is shown in Figure 5. It can be seen from this figure that the most seriously polluted cities are located in North China where SO_2 emissions are high, and in South and Southwest China, such as Chongqing, Guiyang, and Nanning, where sulphur contents in coal are high, and the dispersion capacity of air pollutants is limited due to the effect of mountains.

On the other hand, the annual average concentration of NO_x in all cities is lower than the national standards, in general below $50\mu g/m^3$, due to small number of cars in the cities currently. However, the situation will change because the number of cars is increasing at a speed of 10% annually; there are presently 7 million cars in China. Therefore, NO_x pollution can not be ignored in the future either.

Air quality in rural areas including the counties, villages, and towns, is better than in the middle-size and big cities in China. In general, both of SO_2 and NO_x concentrations are approximately $10\mu g/m^3$, which is close to the levels in Europe and North America, but it is two to three times the value in Japan and South Korea. TSP concentration is much higher, approximately $150\mu g/m^3$, due to the effect of natural dust blown up by wind and the dry climate in northern and/or northwestern China.

In view of the whole country, air pollution in cities is closely related to the emission intensity in these areas. Thus, it is necessary to understand the emission intensity of air pollutants on a regional scale. As an illustration, emission intensity for SO_2 is shown in Figure 6. The emission intensity for SO_2 is large in those provinces which are located in the middle-east China. The emission intensities of NO_x and TSP are similar to that of SO_2.

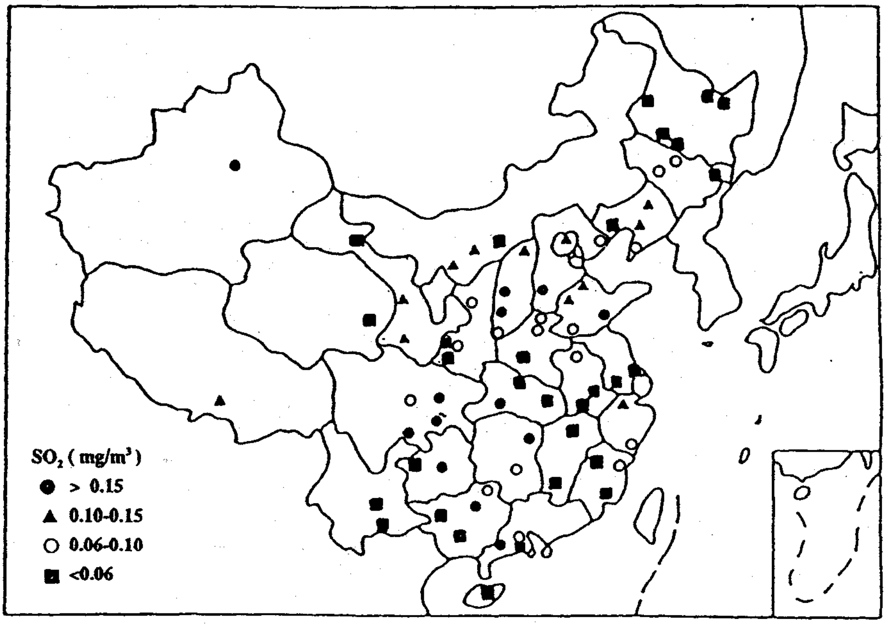

Figure 5. Distribution of the SO_2 concentration in major cities (1992). (Wang, 1993)

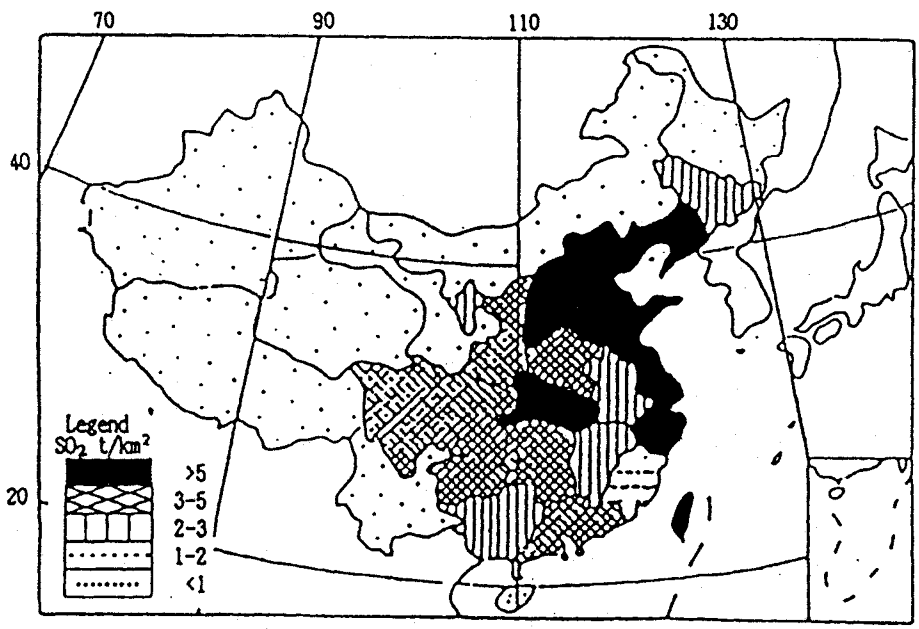

Figure 6. Regional-based emission strength of SO_2 (1990). (Wang, 1993)

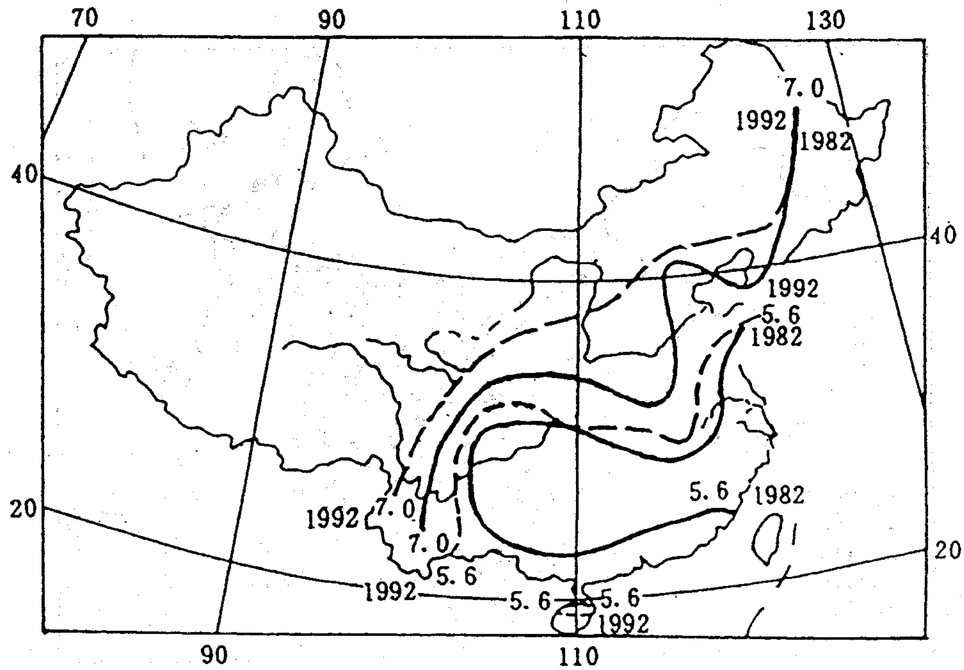

Figure 7. Distribution of the pH values of the precipitation in 1982 and 1992. (Cheng, 1993)

Air quality in any city or region is mainly determined by such factors as pollutant sort, emission amount and characteristics, and environmental geography, which is quite different from one place to another. Thus, factors affecting air quality in different cities differ much from each other. In general, air quality in China is the worse the city is the bigger, and the cities on the plains are better than those in mountainous area. In fact, air quality in extensively rural area is rather fair.

The spatial distribution of pH in precipitation in China 1992 and 1982 is shown in Figure 7. The broken and solid lines represent 1992's pH, and 1982's pH isolines, respectively. It can be seen from the graph that the isolines move to the north and that the distributions of low pH areas have been enlarged during the last 10 years. The most acidic area is located in southeastern China (Wang *et al.*, 1993; Zhao, 1988).

The reason why the phenomenon mentioned above occurred may be explained as follows.

Coal has been the major fuel in China over a long period, accounting for 70% and more among the total energy resources, in which petroleum accounts for about 20% and the cleaner energy resources, such as natural gas and hydropower, account for only 5% and less (Quan, 1993). There will be no significant change in the energy structure in China in the coming decades. Obviously, the SO_2, NO_x, and particulates released during the combustion of the coal are the major sources of the acidification of the precipitation in China, although the mechanisms of the formation of the acidic precipitation may be different; for example, some forms through the washout process and others through the rain out process, depending on different meteorological and geographical conditions. Generally, southern areas with serious acidification of precipitation and frequent occurrence of acidic precipitation are also the areas with serious air pollution and high atmospheric concentration of SO_2 (sometimes the concen-

Table 5. Efficiency of energy utilization by sectors in developed countries and in China.

Items	Efficiency of Energy Utilization (%) In China	In developed countries
Thermal Electricity Generation	28	35-40
Industrial Boilers	55	70-80
Iron and Steel Production	28	50-60
Nitrogenous Fertilizer Production	25	50
Railway Transportation	8	20-25
Commercial and Domestic Use	15-18	50-60

tration of SO_4^{2-} among the anions in the precipitations are as high as 80%). NO_x is also an important precursor, but its contribution is much smaller in comparison with SO_2. For example, the ratio of SO_4^{2-}/NO_3^- in Guiyang is larger than 10. This is quite different from the situation in European and American countries where the contributions from SO_4^{2-} and NO_3^- account for 65% and 35%, respectively. This indicates that the acidic precipitation in China is characterized by rain containing sulfuric acid. Moreover, most of the coal-burning boilers in China are not equipped with desulfurization facilities. Washed or desulfurized coal is used only by few plants and industries. Additionally, at the moment, most of the industrial production technologies and facilities in China are at a low level with high consumptions of energy and raw materials and low efficiency of energy utilization (Table 5). It is estimated that 300 million tons of coal could be saved each year if the energy efficiency in China was as high as that in developed countries like Japan and USA. For the power plants in China, the coal consumption per kwh is as high as 423g (national average). If this value could be reduced to 330g, 80 million tons of coal could be saved and, thereby the large amount of air pollutants could be reduced.

The dominant fuel used in China is coal. Sulfur dioxide is the major pollutant responsible for acidic deposition.

5. Control Policies and Countermeasures

The Chinese government takes the environmental protection and pollution control as a basic national policy, and strives after solution of environmental protection while fostering the development of the economy and society. To promote air pollution control, the government takes comprehensive measures of legislation, administration, social public opinion, and economics.

As mentioned above, the dominant fuel used in China is coal. SO_2 is the major pollutant responsible for acidic deposition. The removal of sulfur from coal prior to combustion is an attractive emission control strategy. Acidic deposition is controled by the atmospheric concentration of SO_2, and in order to reduce the emission of SO_2, a series of policies and countermeasures are taken:

(1) Rationalizing the distribution of industries
   a) Implementing regulation on environment evaluation before construction of any new industry.
   b) Improving old industries of unreasonable distribution
(2) Saving energy, reducing pollutants emission
(3) Revising the fuel structure of domestic usage
(4) Improving technique of combustion
(5) Strengthening regulation on the discharge of gaseous pollutants from automobile
(6) Strengthening environmental legislation
(7) Supporting studies on control technology
(8) Developing energy with low pollution or without pollution

Based on the present situation and sources of the acidic precipitations in China, the reduction of SO_2 emissions, although it is not an easy job, should be the basic countermeasure for the control of the acidic deposition. The measures which have been or will be taken in China for the control of the acid rain are summarized as follows:

1) Developing environmental protection industries and reducing SO_2 emissions

As mentioned in the above sections, the annual consumption of coal in China is as high as 1.1 billion tons and the SO_2 emissions from coal burning are 18 million tons, second only to US. The Chinese government has decided to give priority to the development of environmental protection industries, including the production of desulfurization equipment, new boilers, and coal washing facilities with the purpose to control air pollution and acidic precipitation. It is also decided that a total investment of 15 billion yuan will be made before the year 2000 in order to reduce the SO_2 emissions by 5 million tons. For this purpose, technical innovation should be carried out to increase the energy efficiency and reduce the energy consumption of the industrial production equipment. For large boilers, desulfurization equipment should be installed. At the same time, technologies for making briquette and boilers using briquette should be developed and promoted.

2) Levy on SO_2 emissions

The environmental protection committee under the State Council decided on December 18,1990 to levy on SO_2 emissions with the purposes to restrict SO_2 emissions from industries and collect funds for the control of acidic precipitation. The levy on SO_2 emissions has been practised in Guangdong and Guizhou Provinces and nine cities (Liuzhou, Chongqing, Yibin, Nanning, Guilin, Yichang, Changsha, Qingdao, and Hangzhou) since 1992. The primary output of the practice is very encouraging.

3) Increase in combustion efficiency of coal

It can be seen from Table 5 that the energy efficiency is quite low in China. Therefore, it is very important to increase the combustion efficiency through technical innovations on industrial boilers and about 400,000 small boilers. In this way, a large amount of SO_2 emissions may be reduced and huge amount of energy may be saved. However, this is not an easy job. A long-term effort should be made before a significant improvement could be achieved.

4) Promotion of cleaner energy

The present energy structure in China is dominated by coal. The cleaner energy accounts for a very small percentage. First, shares of cleaner energy should be gradually increased, for example, through the development of hydro power, natural gas, nuclear power, geothermal power, and wind energy. Second, certain fraction of the coal consumed should be converted into cleaner fuels, for example, through the liquefaction and gasification of coal. Undoubtedly, the investment and technology issues should be settled in this regard. These measures are very important for the improvement of the air quality and the control of acidic precipitations.

5) Enhancing regional cooperation

China is a developing country with a population of about 1.2 billion, and is faced with a serious challenge from environmental pollution during the development of its economy. The Chinese government will implement resolutely its basic national policy for environmental protection, take the way of sustainable development, and harmonize the economic development with environmental protection. The Chinese government elaborated and issued "China's Ten Major Countermeasures for Environment and Development" last year just following the "Rio Summit". In addition, "China's Agenda 21" and "Action Plan for China's Agenda 21" are being elaborated. These reflect the leading strategy of China to resolve its environmental problems through its own efforts.

However, the acidic precipitation issue arises in some regions and it is getting more and more serious. As already mentioned, acid rain often causes problems beyond the borders because it sometimes falls several thousand kilometers away from the emission sources, and similar problems in other eastern Asian countries, such as in Japan and Korea, may occur. The acidic precipitation, therefore, is a regional environmental problem in East Asia. To clarify the acidic deposition formation mechanism, dispersion, effects on ecosystems, and their control measures, it is also important to enhance the international cooperation. China, as a member of the international society and an East Asian country, will fulfill its responsibility and obligation in this regard.

The pollution control investment increased to 4.85 billion yuan (RMB) from 1981 to 1985, accounting for 0.57% of GNP, and further increased to 10.906 billion yuan from 1986 to 1990, making up 0.63% of GNP. The annual investments are listed in Table 6. It can be seen that the annual investment increased four fold from 1981 to 1990, and a further increase of the percentage will take place.

Annual investment for air pollution treatment is listed in Table 7. It can be seen that the investment for air pollution treatment doubled from 1985 to 1990. As a result, the smoke dust emissions from coal burning were under 14 million tons, and the industrial dust emissions were cut down to 40%.

However, we must pay attention to the air pollution that is controlled on the basis of high pollution level. It will take a long period, tremendous efforts, and large funds to thoroughly improve the urban air quality unless new techniques in air pollution control are developed. The extent of the problem varies in different cities. Of the cities listed above, northern cities appear to have the most severe problem with respect to TSP, whereas the southern cities have higher SO_2 levels.

It was mentioned earlier in this paper that the major reason for the higher levels of particulate and SO_2 in Chinese cities is the direct combustion of coal in small and inefficient boilers. All of the coal-fired power plants and large industries have installed electrostatic precipitator

Table 6. The environmental protection investment over the years and its rate in GNP in China.

Year	Environmental protection investment (billion yuan)	GNP (billion yuan)	Environmental protection investment rate in GNP (%)
1981	2.500	477.3	0.52
1982	2.866	519.3	0.55
1983	3.072	580.9	0.53
1984	3.336	696.2	0.48
1985	4.850	855.8	0.57
1986	7.389	969.6	0.76
1987	9.189	1130.1	0.81
1988	9.998	1398.4	0.71
1989	10.249	1578.9	0.65
1990	10.906	1740.0	0.63

Sources: China Statistics Yearbook, China Urban Construction Yearbook, Annual Report on Environmental Statistics.

Table 7. The waste gas treatment state in China (1985–1990).

Item	Unit	1985	1986	1987	1988	1989	1990
Waste gas treatment funds	billion yuan	0.73	0.96	1.24	1.53	1.58	1.48
Total emissions	billion m^3	7397.00	6967.90	7727.50	8238.00	8306.50	8542.20
SO_2 emissions	million tons	13.25	12.50	14.12	15.23	15.56	14.95
Smoke dust emissions	million tons	12.95	13.84	14.45	14.86	13.98	13.24
Industrial dust emissions	million tons	13.05	10.75	10.04	11.25	8.40	7.81
New added treatment capacity	billion m^3	617.70	370.40	319.60	434.30	473.40	442.10

Source: Annual Report on Environmental Statistics.

to reduce emissions of particulate, but almost without desulfurization equipment because it is very expensive.

At present, the measures to switch to cleaner energy sources, such as natural gas and liquefied petroleum gas, centralized heating supply as well as coal gasification have been spread rapidly in cities. In this respect, some techniques for boilers, including industrial and power plant boilers, have been developed such as industrial briquette, high efficiency precipitator, coal combustion sulphur retention bubbling boilers, phosphate ammonium fertilizer process in FGD (Flue Gas Desulfurization), rotating spray in FGD process, and active carbon catalyst to produce sulfuric acid in FGD. The desulfurization plants are very expensive and large-scale desulfurization installation might not be equipped in the near future.

6. Summaries and Conclusions

Results of several nationwide projects identified the status of acidic deposition in China. The results show that the acidic deposition mainly occurs in the south of Yangtze River, especially in four regions including (1) Sichuan Basin; (2) Guizhou Province; (3) Hunan, Hubei, and Jianxi provinces; (4) Coastal provinces areas of Fujian, Guangdong . Limited acidic deposition was recorded in northern and eastern China. Local pollution is the major reason for acidic deposition, whereas long range transport plays a relatively minor role. The area affected by acidic deposition accounts for about 6.8 % of the total area of the state and the area with serious problem accounts for 11.7 % of the total area affected by acidic deposition.

The dominant fuel used in China is coal. SO_2 is the major pollutant responsible for acidic deposition. To control acidic deposition, the atmospheric concentration of SO_2 must be controlled by reducing the emission of SO_2. A series of policies and countermeasures are taken to achieve this target. International cooperation has been vital in persuading states to attempt to control the effects of acidic rain.

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