PROPOSED SCENARIOS FOR TOTAL EMISSIONS CONTROL OF SO_2 EMISSIONS DURING THE TENTH FIVE-YEAR PLAN IN CHINA

WANG Jinnan CAO Dong WU Xuefang MENG Fan[1]

(Chinese Research Academy of Environmental Sciences)

Abstract: China continues its strategy of total emissions control (TEC) or total load control for SO_2 in the Tenth Five Years (2001~2005). This paper will analyze the status of SO_2 TEC in China during the *Ninth Five-Years* (1996~2000). Based on the results of the analysis and the theory of divisional air resources, this paper will study the target of total SO_2 emissions nationwide and its allocation for different regions during the *Tenth Five-Year Plan* (TFYP), then propose an initial scenario for the TEC of SO_2 at the national level and for the SO_2 and Acid Rain Control Areas (the "Two Control Areas") during the *TFYP.* Based on the study conducted by the authors, we recommend controlling the total emissions level of SO_2 to 19 million tons by 2005. The allocation of a SO_2 TEC target to a region provides a permitted level of SO_2 emissions for the pilot regions where SO_2 emission trading is being conducted.

Key words: total emission control; SO2 emissions; environmental protection plan

1 Status of SO_2 Emissions in China

On the basis of the "Environmental Protection Plan during the 'Ninth Five-Year Plan' in China", which was issued by the China State Environmental Protection Administration (SEPA) and approved by the State Council of the Central Government, by the end of 2000 the total SO_2 emissions nationwide were to be controlled to 24.6 million tons, and the air quality in 47 key cities was to reach national standards set by the air environmental functional zones[2]. According to the statistics of SEPA, the total SO_2 emissions nationwide in 2000 was 19.95 million tons, which was lower than the national target set by SEPA for 2000. The results from the attainment of these targets will decide the formulation of the SO_2 TEC target for the "Tenth Five-Year Plan".

1.1 Status of SO_2 emissions

Total SO_2 emissions during the five years from 1995 to 2000, based on statistics collected by SEPA, are listed in Table 1. In 2000, total SO_2 emissions nationwide amounted to 19.95 million

[1] The viewpoint, conclusion and recommendation proposed in this paper are developed from initial studies made by the authors. They do not represent the views of the Chinese Research Academy of Environmental Sciences or the State Environmental Protection Administration (SEPA) of China. The scenario and specific indicators for control of SO_2 during the "Tenth Five-year Plan" will be based on "Total Load Control Plan for Pollutants Emission during 'Tenth Five-year Plan' of China" to be issued by SEPA in 2001.

[2] According to the requirements for air environmental functional zones, the density of SO_2 in the air of the 47 cities has to meet the National Standard Class 2 for Air Quality, i.e. the annual volume should be 0.06 mg/m^3 on average. The National Standard Class 3 for SO_2 in China is 1.0 mg/m^3, and the corresponding standard of WHO is 0.05 mg/m^3.

tons, a decrease of about 20 % relative to 1996, the SO_2 emissions of which still ranks the first in the world in 2000. The data show that the SO_2 emission target for 2000, as established by the government, was achieved in 1999 and in 2000. The regions that made significant contributions to SO_2 emissions were primarily composed of areas with high sulfur-content coal, large-scale energy production, and high levels of energy consumption. The top four regions with the largest SO_2 emissions include Shandong Province, Guizhou Province, Hebei Province and Shanxi Province, with SO_2 emissions of 1.83 million tons, 1.49 million tons, 1.33 million tons and 1.24 million tons, respectively. The SO_2 emissions in these four provinces accounted for 31.7% of the nationwide total. SO_2 emissions are associated with several key sectors: the power generation and coal gas production sectors contributed 41% of the total industrial SO_2 emissions nationwide, approximately 6.53 million tons in 2000.

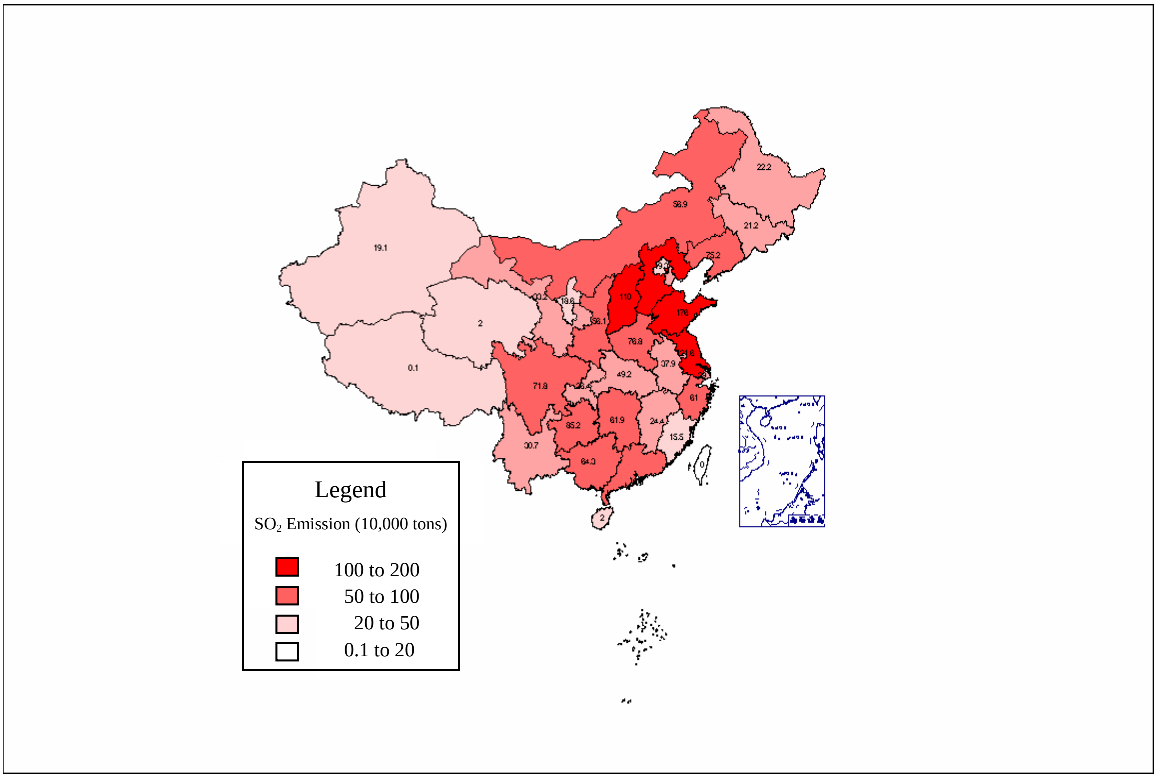


Figure 1 Distribution of SO_2 Emission by Region in China in 2000
Resource: SEPA, Statistic Report for Environment in 2000

During the period of the "Ninth Five-Year Plan", the large decrease in SO_2 emissions was mostly the result of:

(1) The government implemented restructuring policies affecting the industrial make-up of China, closing small-sized enterprises in 15 sectors and closing small coalmines. Statistics show that by the end of 1999, since the implementation of a measure to close small coalmines and reduce production from the coal mining industry, 31,200 illegal coalmines and mines with improper layouts were cancelled or closed. This resulted in reductions of coal production by 268 million tons, including reductions of high sulfur-content coal by 22 million tons (SEPA, 2000). This result is equivalent to a reduction of more than five million tons of SO_2 emissions.

(2) In the power generation sector, 2.9 million KW of small thermal power units were closed, including 2 million KW of capacity in the "Two Control Zones". Since 1996, nearly 0.8 million tons of SO_2 emissions were reduced in the "Two Control Zones" (SEPA, 2000).

(3) The distressed economies, with numerous large- and medium-sized state-owned enterprises (SOE) suffering heavy losses, resulted in idled production lines that created a decline in energy demand. Faster economic growth in 2000 caused SO_2 emissions to rise again and it is estimated that SO_2 emissions may climb to 20 million tons.

(4) Cities in China are now increasing construction of facilities for environmental protection, especially to decrease energy consumption, promote the utilization of cleaner energy, and optimize the industrial make-up and distribution of pollution sources in the city. These have played a significant role in reducing SO_2 emissions.

Table 1 Total SO2 Emissions from 1995 to 2000 (Unit: 10,000 tons)

Province	Emission Target in 2000	Actual Emission in 1995	Actual Emission in 1996	Actual Emission in 1997	Actual Emission in 1998	Actual Emission in 1999	Actual Emission in 2000
Beijing	38.0	38.29	36.17	34.82	30.51	23.35	22.4
Tianjin	33.0	33.60	36.00	27.20	22.99	24.24	32.9
Hebei	170.0	166.00	158.10	146.02	140.30	132.62	132.13
Shanxi	181.0	157.85	108.00	182.01	141.99	123.95	120.16
Inner Mongolia	80.0	72.95	78.90	75.31	72.80	69.09	66.38
Liaoning	107.7	102.90	110.20	112.43	99.19	93.74	93.24
Jilin	28.0	25.50	23.87	28.66	28.39	29.37	28.57
Heilongjiang	31.0	28.96	32.10	30.56	30.01	29.41	29.66
Shanghai	50.0	51.06	57.16	50.85	48.89	40.31	46.50
Jiangsu	139.0	139.09	141.31	136.98	125.46	97.97	120.18
Zhejiang	61.0	61.39	80.40	67.28	64.55	63.64	59.27
Anhui	50.0	50.03	45.80	48.86	42.35	40.98	39.53
Fujian	30.0	23.48	33.50	47.48	16.50	19.04	22.50
Jiangxi	63.0	63.39	43.50	40.63	30.46	28.43	32.31
Shandong	243.0	243.80	211.80	247.32	225.89	182.98	179.59
Henan	154.0	153.58	121.00	92.26	100.29	84.97	87.69
Hubei	65.0	65.06	64.62	57.95	56.88	55.33	56.04
Hunan	88.0	88.16	99.00	82.09	72.21	75.84	77.25
Guangdong	100.0	93.74	77.07	69.30	67.88	69.49	90.47
Guangxi	102.0	102.46	84.45	99.26	70.09	58.35	83.03
Hainan	8.0	3.78	2.93	2.08	2.04	2.24	2.04
Chongqing	100.0	0.00	95.20	0.00	68.04	94.11	83.94
Sichuan	110.0	215.60	155.52	103.22	140.77	81.27	122.30
Guizhou	140.0	140.30	90.00	176.48	192.79	149.45	145.01
Yunnan	44.0	44.70	51.30	41.04	36.01	33.66	38.59
Tibet	0.2	0.10	0.30	0.10	0.14	0.09	0.08
Shaanxi	114.9	99.92	99.43	75.84	66.01	64.78	62.33
Gansu	50.0	44.05	43.48	42.93	38.34	31.24	36.85

Qinghai	5.0	3.93	2.95	3.73	3.13	3.10	3.20
Ningxia	23.0	20.40	23.31	22.18	21.52	20.79	20.58
Sinkiang	41.0	35.49	35.14	30.91	33.56	33.71	31.05
Total	2449.8	2369.56	2242.51	2175.78	2090.0	1857.53	1995

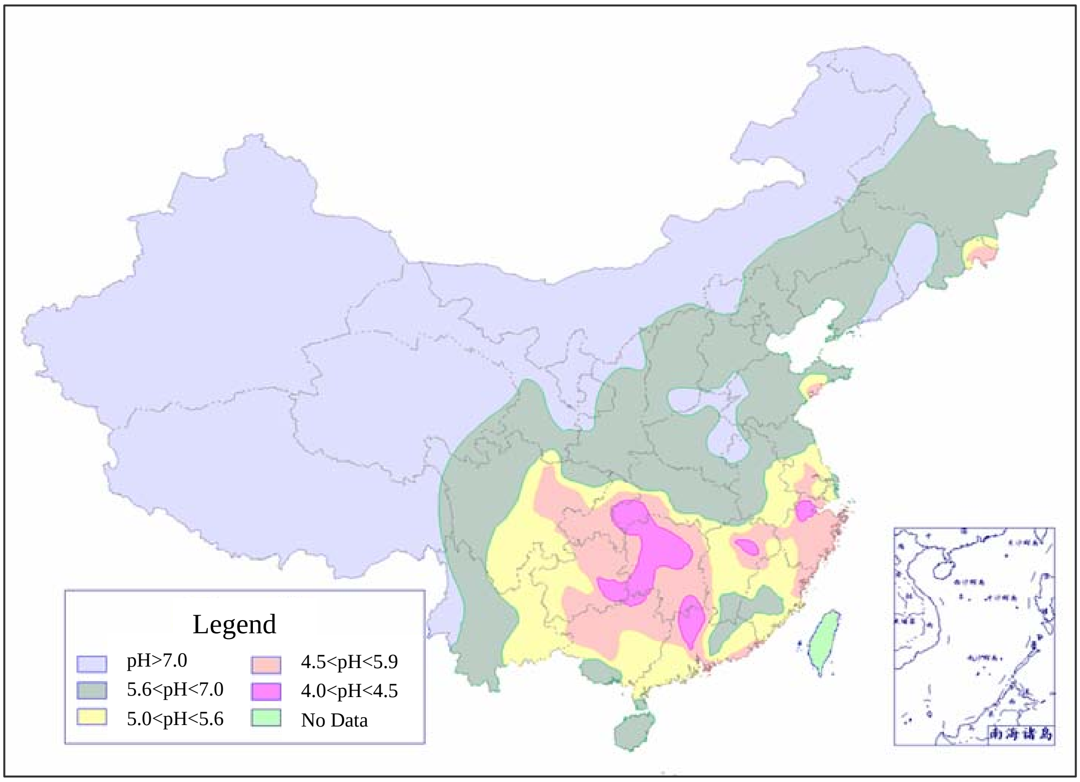
Source: WANG Jinnan, etc., 2000

1.2 Urban SO_2 Pollution and Acid Rain

Based on statistics from monitoring in 338 Chinese cities in 2000, the concentration of SO2 in approximately 33.1% of the cities did not meet the National Standard Class 2 for Air Quality (0.06mg/m3 for normal residential areas), 15% of the cities were in excess of the National Standard Class 3 for Air Quality (0.10mg/m^3 for special industrial zones). The air quality in 109 cities was worse than WHO guidelines, accounting for over 33% of the monitored cities (Chinese General Station for Environmental Monitoring, 2000). The cities with poor air quality were primarily distributed in Guizhou, Sichuan, Guangxi, Shanxi, Shandong, Hebei, Shaanxi, and Gansu Province and Chongqing and Beijing City, which corresponds with the cities with large SO_2 emission (see Figure 2). In general, the average concentration of SO_2 in the ambient air dropped slightly in recent years and the trend of air quality deterioration due to SO_2 emissions is slowing.

In recent years, the general distribution of acid rain pollution in China remained unchanged. Acid rain now dominates nearly 30% of China, covering a large area in the southern region of the Yangtze River and the eastern part of the Qinghai-Tibet Plateau and Sichuan Basin. Regions with acid rain problems are located in central, southwestern, southern, and eastern China. In the southern region of China, serious acid rain is still a problem in some areas. In 1998, the average pH of precipitation ranged from 4.13~7.79 nationwide. The cities with an annual average pH value lower than 5.6 accounted for 52.8% of cities. Seventy-three percent of the southern cities with reported values had average annual pH values lower than 5.6, and a few cities in Zhejiang, Hunan, Guangdong, Guizhou and Jiangxi Province had average annual pH values lower than 4.5. The annual pH value in a few northern cities was lower than 5.6 on average. Acid rain occurs in nearly all of the southern cities in China and 30% of northern cities. Seventy-seven percent of cities in China have experienced acid rain.

Figure 2 Distribution of Cities With Heavy SO_2 Polluion in China
Source: Brief to National Environmental Quality of China 2000



2 Regional Division of Air Environmental Resources in China

2.1 Characteristics of Air Environmental Resources

Researches by the Chinese Research Academy of Environmental Sciences (CRAES) found that in a normal year, the atmospheric transport of acidic materials (primarily SO_2 and NO_x) has the following characteristics:

(1) In the eastern region of China north of 40 degrees latitude, the acidic materials are normally transported from the west or northwest; in northern and northeastern China it is transported from the west. With the increase in the altitude, the transport of pollution from the west shifts southward and reaches 30 degrees latitude at a height of 1,500m. At a height of 2,000m, the transport is from the west in eastern China and east in the coastal area of China. In addition, there is some transport from Mongolia and Russia.

(2) The transport in southwestern China is from the south below a height of 1,500m and primarily stays within the borders of China; transport in western and northwestern regions also stays within the borders of China. In the inland area of China, the transport is through various regions within China, including intra-province and inter-province transport. There is also some circular transport in these regions.

(3) From a macro view, the region north of 40 degrees latitude, the eastern coastal area, and various provinces, there exist both inflow and outflow transport, but the latter normally dominates these regions. Near Shandong Biland, transport exists within China and beyond its borders. In the region south of 35 degrees latitude, the inter-province and intra-province

transport plays a dominant role. Some circular airflow also occurs in these regions.

The air resources in China have been divided into 16 regions according to geographic features, characteristics of atmospheric capacity (such as the susceptibility, sensitivity, and adaptability of a region to air pollution) (REN Zhenhai, 1998). It also facilitates environmental quality assessment and control. The regions include (1) Qinghai-Tibet and Northwest Sichuan Plateau Region; (2) Yunnan-Guizhou Plateau Region; (3) Sinkiang Region; (4) Northern Region covering Heilongjiang Province, Guansu and Inner Mongolia; (5) Northeast Plain Region; (6) Lanzhou Region; (7) South-Shaanxi Basin Region; (8) Shanxi Basin Region; (9) Two-lake Basin Region; (10) Jiangxi Basin Region; (11) Sichuan Basin Region; (12) Coastal Region of Fujian and Zhejiang; (13) Guangdong and Guangxi Region; (14) Region covering the Yangtze Delta and Hangzhou Bay; (15) Henan and Anhui Region; and (16) North China Plain Region.

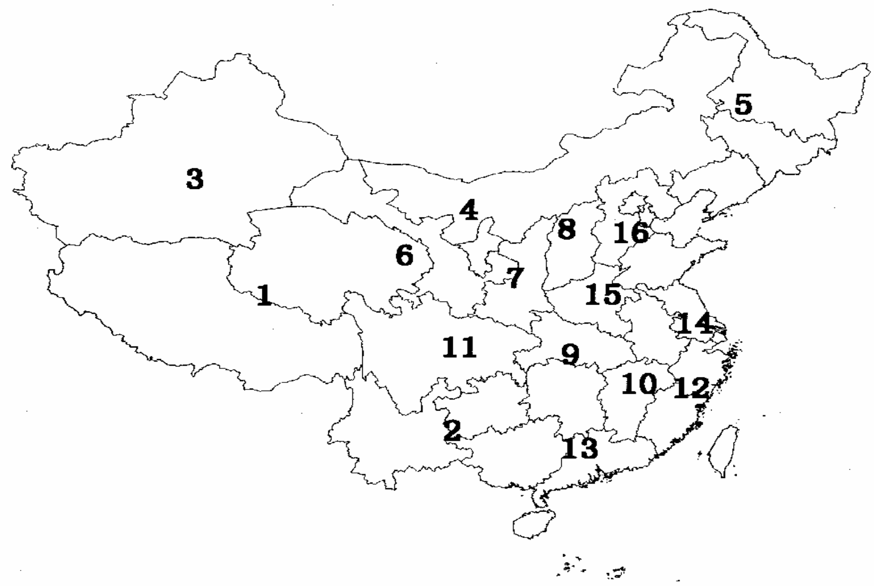


Figure 3   16 Sub-regions of Air Environmental Resources in China

2.2 Potential Fluctuation of Air Emissions in Each Region

Research conducted by CRAES indicates that if the national energy composition, industrial make-up, distribution of cities, and climatic conditions of China remain unchanged, only when the overall SO_2 emissions are controlled at the level of approximately 12 million tons can SO_2 concentrations in a majority of Chinese cities reach the National Standard Class 2 for Air Quality. That is to say, the environmental capacity of China for SO_2 emissions is around 12 million tons. Based on the results from the regional division of air resources in 16 regions, which was also conducted by CRAES, Table 2 lists regions that have to reduce air emissions and those that may have some additional capacity in the upcoming 10 years. The table shows that coastal regions with fast economic growth and areas with heavy SO_2 pollution and acid rain do not have capacity for more SO_2 emissions, but western regions (except for large- and medium-sized cities) do have some additional capacity.

Table 2 Analysis for Potential Fluctuation of Air Emissions in Each Region

Province and Region	Regions with additional SO_2 emissions capacity	Regions where SO_2 emissions must be reduced
Inner Mongolia	East and west	Hua'de, Huhehot and Dongsheng Region in the middle of Inner Mongolia
Heilongjiang	North	Qiqihar region in the southwest, Harbin in the south, north of Xingkai Lake in the southeast
Liaoning	Northwest	Shenyang and Anshan in the middle of Liaoning and the south of Jiaodong Biland
Guangxi	Northeast	Liuzhou in the north and Nanning in the south
Sinkiang	Other regions	Urumchi region
Gansu	Northwest	Lanzhou and Tianshui Region in the southeast
Ningxia	South	Yinchuan Region in the middle of Ningxia
Shanxi	Region around He'qu in the northwest	Region around Taiyuan in the middle and east, the northeast and the south
Shaanxi	Region in the north of Yan'an	Guanzhong Plain in the south, the region in the south of Qingling Mountain, and Hanzhong Plain
Shandong	East end of the biland	Jinan in the middle of Shandong, and Qingdao in the south-east
Fujian	Southwest	Coastal area around Fuzhou and Fuding
Jilin		Middle and southern area
Hebei (including Beijing and Tianjin)		East, Shijiazhuang, Xingtai, the north of Taihang Mountain and the area around Yanshan Mountain, the region covering Beijing, Tianjin and Tangshan
Hubei	West Hubei in the southwest	Hankou Region in the east
Hunan	Sangzhi and Jishou in the northwest	A large majority of regions in the east, and Changsha
Hainan	A large majority of Hainan	North, Haikou
Guangdong	East and north	Mid and south region, Guangzhou and Shenzhen
Anhui	Most regions with low emission	Northeast, and the Bengbu Region
Jiangxi	Xun'wu in the south	Region around Nanchang in the north
Yunnan	A large majority of Yunnan	The east region along the border, and region around Xingren
Sichuan		The south, Chongqing, Yibing, Chengdu
Guizhou	The region along the eastern border	Southwest, Guiyang
Zhejiang	Southwestern regions with low emissions	Northeast, Hangzhou and coastal area
Henan	Southeastern regions with low emissions	North, An'yang, mid of He'nan, Zhengzhou and other regions
Shanghai, Jiangsu		Shanghai City, the south of Jiangsu and Nanjing City

3 Scenario for Total Emissions Control of SO_2 Emissions

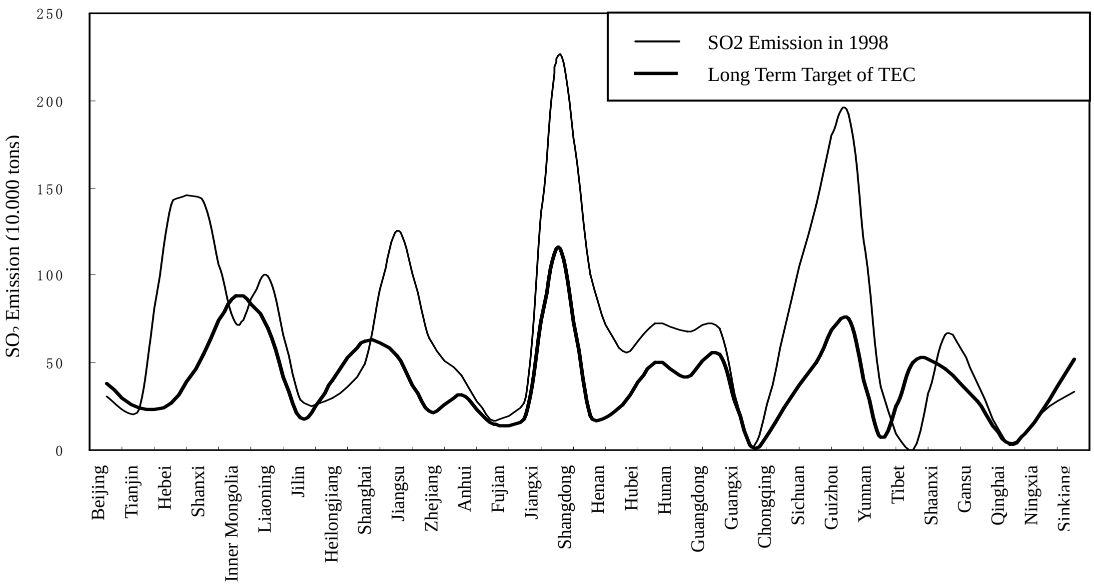
3.1 Methods for Identifying Scenarios for TEC of SO_2 Emissions

At present, there are two major methods for developing SO_2 emissions targets. One is a grandfathered approach, i.e. on the basis of SO_2 emissions in past years and trends for the future, to identify target SO_2 emissions. The SO_2 TEC target for 2005 identified using this method is comparatively stringent. The other method is an environmental capacity-based approach, i.e. start from the targets for air quality and control of acid rain in the "Tenth Five-Year Plan" of China and, based on the air capacity of each region and indicators from SO_2 control planning for the "Two Control Zones", identify the total capacity for SO_2 emissions at the national and provincial level. At the national level, the SO_2 TEC target should have some spare capacity to provide for the development of western China. In this paper, the latter method will be used in developing a scenario for TEC of SO_2 during the "Tenth Five-Year Plan".

While identifying the SO_2 emissions target at local levels, the following three principles were used: (1) Reducing SO_2 emissions in regions with high concentrations of SO_2 in the ambient air is a priority, i.e. comparing environmental quality monitoring data from 1998 against the National Standard Class 2, the worse the air quality of the region, the larger the SO_2 emissions reduction. Therefore, a set of adjusting coefficients for regional air quality were formulated. For regions whose air quality reached the National Standard Class 2 for Air Quality, SO_2 emissions also had to decrease albeit at a lower proportion so as to ensure a continuous decline in total emissions all over the county. (2) Reducing SO_2 emissions in regions with large SO_2 emissions is also a priority. Some provinces and cities currently achieve the National Standard Class 2 for Air Quality, but their SO_2 emissions are very high. The total emissions in these regions, such as Shandong, Guizhou, Shanxi, Hebei, Jiangsu and Sichuan, must be reduced. (3) Reducing SO_2 emissions in regions with high peak values are another priority, i.e. in regions whose current SO_2 emissions far exceed the ideal emissions target for the long term[3] (such as the provinces and cities with high peak values in Figure 4), an emphasis should be placed on reducing their SO_2 emissions, such as Shandong, Guizhou, Shanxi, Hebei, Jiangsu and Sichuan.

Figure 4 Comparison between Current SO2 Emissions and the Ideal TEC Target for the Long Term in Each Region of China
(Source: Wu Xuefang, 2000)

[3] Ideal Emission Target for the Long Term means the permitted SO_2 emissions satisfying the National Standard Class 2 for Air Quality, i.e. the thick black line in Figure 5.



3.2 Scenario for Total Emissions Control of SO_2 in Air

Using the capacity-based approach to develop SO_2 TEC targets for China, the national SO_2 TEC target in 2005 should be 18.2 million tons, including 0.8 million tons of spare capacity to account for development in western China. By 2005, the total SO_2 emissions in the “Two Control Zones” must decline to 10 million tons. Table 3 lists the TEC target for SO_2 emissions at the national and provincial levels in the “Two Control Zones”. The allocation of the remaining TEC for 0.8 million tons is listed in Table 4.

Table 3 Scenario for SO_2 TEC during the “Tenth Five-Year Plan” of China (Unit: 10,000 tons)

Province	**Emission Target in 2000**	**Actual Emission in 2000**	**Emission Target for 2005**	**Target for the Two Control Zones**
Beijing	38.0	22.4	18.8	15
Tianjin	33.0	32.9	29.0	25
Hebei	170.0	132.13	120.0	50
Shanxi	181.0	120.16	110.0	36
Inner Mongolia	80.0	66.38	68.2	38
Liaoning	107.7	93.24	98.9	67
Jilin	28.0	28.57	28.0	6
Heilongjiang	31.0	29.66	30.0	0
Shanghai	50.0	46.50	45.0	45
Jiangsu	139.0	120.18	100.0	82
Zhejiang	61.0	59.27	61.0	55
Anhui	50.0	39.53	36.0	12
Fujian	30.0	22.50	25.0	17
Jiangxi	63.0	32.31	30.5	16

Province	Emission Target in 2000	Actual Emission in 2000	Emission Target for 2005	Target for the Two Control Zones
Shandong	243.0	179.59	150.0	69
Henan	154.0	87.69	100.1	15
Hubei	65.0	56.04	54.3	33
Hunan	88.0	77.25	65.0	51
Guangdong	100.0	90.47	69.3	45
Guangxi	102.0	83.03	68.1	43
Hainan	8.0	2.04	2.2	0
Chongqing	100.0	83.94	70.0	37
Sichuan	110.0	122.30	100.0	85
Guizhou	140.0	145.01	140.0	70
Yunnan	44.0	38.59	36.0	23
Tibet	0.2	0.08	0.2	0
Shaanxi	114.9	62.33	75.0	26
Gansu	50.0	36.85	35.0	20
Qinghai	5.0	3.20	5.0	0
Ningxia	23.0	20.58	15.7	13
Sinkiang	41.0	31.05	33.6	6
Total in China	2449.8	1995	1820	1000

Table 4 Scenario for SO_2 TEC in Western Provinces (Unit: 10,000 tons)

Region	Emission Targets in 2000	Actual Emission in 2000	Emission Target in 2005	Additional Allowance for Western Provinces	Total Emission Target
Inner Mongolia	80.0	66.38	68.21	7.0	76.2
Guangxi	102.0	83.03	68.07	12.0	80.1
Chongqing	100.0	83.94	70.00	10.0	80.0
Sichuan	110.0	122.30	100.00	5.0	105.0
Guizhou	140.0	145.01	140.00	5.0	145.0
Yunnan	44.0	38.59	36.01	6.0	42.0
Tibet	0.2	0.08	0.20	2.0	2.2
Shaanxi	114.9	62.33	81.00	4.0	85.0
Guansu	50.0	36.85	35.00	10.0	45.0
Qinghai	5.0	3.20	5.00	5.0	10.0
Ningxia	23.0	20.58	15.68	7.0	23.0
Sinkiang	41.0	31.05	33.56	7.0	40.6
Total	810.1	693.34	652.73	80.0	734.1

4 Conclusion

Based on our research, the SO_2 TEC target in China for 2005 should be 19 million tons, within which the SO_2 TEC target in the “Two Control Zones” should be controlled to 10 million tons.

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