THE RELATIONSHIPS BETWEEN REGIONAL INDUSTRIAL STRUCTURE AND ENVIRONMENTAL LOADING IN CHINA

Tohru Futawatari [1]

Hidefumi Imura [2]

Abstract

A main cause of environmental problems in China is the large emission of pollutants from energy and industrial sectors. Characteristics of pollution, however, vary in regions depending upon the industrial structure of the respective regions. This study investigates the relationship between regional industrial structures and environmental loading (i.e., emission of air and water pollutants and generation of solid wastes) in China based on economic and environmental data between 1980 and 1995. The coastal region, including the provinces of Jiangsu, Shandong, and Guangdong, is making rapid economic growth based on industries with relatively small environmental loading such as machinery, electric appliances and electronic devices, textiles, and chemical fibers. On the contrary, industrial development in other provinces is generally accompanied by the expansion of polluting industries such as steel production and electric power generation.

KEYWORDS: *environmental problems in China, economic growth in China, industrial structure, air pollution, water pollution, solid wastes*

1. Introduction

Rapid economic growth in China is causing serious environmental problems. They are of great regional variation in their nature and causes: the regions of the country are at various levels of economic growth, having different industrial structures and natural conditions, and different background of environmental problems. There are the cities of the coastal region that are most having the fruits of economic growth caused by national policy of the modernization. They, however, are faced with problems such as overpopulation due to immigration from rural areas, traffic congestion and air pollution caused by the increasing number of motor vehicles, and water pollution in rivers due to the delay in the improvement of urban sewage systems. Air pollution in some industrial cities, in particular, have exceeded a tolerable level, due to the rapid expansion of industrial production by obsolete facilities and equipment using a large amount of high sulfur content coal. On the other hand, inland rural areas are suffering from entirely different problems such as poverty and poor sanitation (NEPA China, 1994).

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1 D. Eng., Associate Professor, School of Health Sciences, University of Occupational and Environmental Health, Japan, Kitakyushu 807-8555, Japan

2 D. Eng., Professor, Inst. of Environmental Systems, Faculty of Eng., Kyushu University, Fukuoka 812-8581, Japan

Today's China is confronted with the dual task of developing the economy and protecting the environment. It has made environmental protection one of its basic national policies. Central and local environmental administration systems have been improved. A number of environmental laws were made and regulatory standards have been strengthened. Thanks to these efforts, there has been notable improvement in the quality of the environment in some cities (NEPA China, 1994). However, the speed of environmental improvement is slow because of various reasons: very rapid economic growth, less stringent regulatory standards, an ineffective enforcement system, insufficient environmental awareness, and the financial shortage for introducing advanced control technology.

Major causes of environmental problems will change according to the stage of economic development of the country. Current environmental problems in China are associated with its rapid economic growth propelled by industrial production expansion. They are reminiscent of the problems Japan experienced in the course of its rapid economic growth period. In such cases, environmental problems differ among regions, depending upon the regional industrial structure; some areas are specialized in polluting heavy industries while some rely on less polluting industries such as electronics and machinery. The objective of this study is to investigate the relationship between regional industrial structure and air and water pollution in China. Firstly, it identifies the location of various industries and the regional industrial structure of the country. Then, it analyzes the characteristics of industrial emissions of air and water pollutants and solid wastes in the provinces and the relationship between regional industrial structure and environmental loading.

2. Regional Characteristics of Economic Development and Industrial Location in China

2.1 Changes in Population and Economic Development by Province

Economic development in China exhibited large regional gaps and disparities. Table 1 demonstrates the changes in population, GDP (Gross Domestic Product) and per capita GDP in the provinces of China over the period between 1980 and 1995. Provinces such as Sichuan, Shandong and Henan kept their large populations during the period. Beijing City achieved a 141them. The official statistics, however, do not take into account the migrant population from rural villages to large cities.

In terms of GDP, Jiangsu, Shanghai and Sichuan were the three largest regions in 1980, but they were replaced by the provinces of Guangdong, Jiangsu and Shandong in 1995. Figure 1 demonstrates the change in the share of provincial GDP to the national GDP between 1980 and 1995. The largest increase in GDP share was recorded in the coastal provinces such as Fujian, Guangdong and Zhejiang. The increase in the share for large cities such as Beijing, Tianjin and Shanghai was not very significant.

In 1980, Shanghai had the highest per capita GDP (2,720 yuan), followed by Beijing and Tianjin. It was 12.5 times as large as the value of the poorest province, Guizhou (217 yuan). In 1995 as well, Shanghai (17,403 yuan), Beijing (11,150 yuan) and Tianjin (9,768 yuan) were the richest, while Guizhou (1,796 yuan) was the poorest. The gap in per capita GDP among regions, especially between large cities in the coastal region, the eastern region and the rural provinces in the inland, middle and western regions are still large as shown in Figure 2. The increase in per capita GDP was most remarkable in the southeast coastal provinces such as

Table 1. Changes of regional population, GDP and per capita GDP.

Region	1980					1995					1995/1980		
	Population (10,000 Person)	Population (%)	GDP (100 million yuan)	GDP (%)	GDP per Capita (yuan)	Population (10,000 Person)	Population (%)	GDP (100 million yuan)	GDP (%)	GDP per Capita (yuan)	Population (-)	GDP (-)	GDP per Capita (-)
Beijing	886	0.90	139	3.11	1,571	1,251	1.03	1,395	2.39	11,150	1.41	10.03	7.10
Tianjin	749	0.76	104	2.32	1,382	942	0.78	920	1.58	9,768	1.26	8.89	7.07
Hebei	5,168	5.24	219	4.90	424	6,437	5.31	2,850	4.89	4,427	1.25	13.00	10.43
Shanxi	2,476	2.51	108	2.41	435	3,077	2.54	1,092	1.88	3,550	1.24	10.15	8.17
Inner Mongolia	1,876	1.90	65	1.46	347	2,284	1.89	833	1.43	3,647	1.22	12.78	10.50
Liaoning	3,487	3.53	266	5.96	763	4,092	3.38	2,793	4.79	6,826	1.17	10.49	8.94
Jilin	2,211	2.24	-	-	-	2,592	2.14	1,129	1.94	4,356	1.17	-	-
Heilongjiang	3,204	3.25	218	4.88	681	3,701	3.06	2,015	3.46	5,443	1.16	9.24	8.00
Shanghai	1,147	1.16	312	6.98	2,720	1,415	1.17	2,463	4.23	17,403	1.23	7.90	6.40
Jiangsu	5,938	6.02	322	7.20	542	7,066	5.83	5,155	8.85	7,296	1.19	16.02	13.46
Zhejiang	3,827	3.88	178	3.99	466	4,319	3.57	3,525	6.05	8,161	1.13	19.75	17.50
Anhui	4,893	4.96	138	3.09	282	6,013	4.96	2,004	3.44	3,332	1.23	14.50	11.80
Fujian	2,518	2.55	86	1.92	341	3,237	2.67	2,161	3.71	6,674	1.29	25.15	19.56
Jiangxi	3,270	3.31	111	2.49	340	4,063	3.35	1,205	2.07	2,966	1.24	10.84	8.73
Shandong	7,296	7.39	294	6.59	404	8,705	7.19	5,002	8.59	5,747	1.19	16.99	14.24
Henan	7,285	7.38	229	5.13	315	9,100	7.51	3,003	5.15	3,300	1.25	13.10	10.49
Hubei	4,684	4.75	199	4.46	426	5,772	4.77	2,391	4.10	4,143	1.23	11.99	9.73
Hunan	5,281	5.35	192	4.29	363	6,392	5.28	2,196	3.77	3,435	1.21	11.45	9.46
Guangdong	5,228	5.30	246	5.50	470	6,868	5.67	5,382	9.24	7,836	1.31	21.90	16.67
Guangxi	3,538	3.58	99	2.20	279	4,543	3.75	1,606	2.76	3,535	1.28	16.30	12.69
Hainan	552	0.56	-	-	-	724	0.60	364	0.63	5,030	1.31	-	-
Sichuan	9,820	9.95	309	6.91	315	11,325	9.35	3,534	6.07	3,121	1.15	11.44	9.92
Guizhou	2,777	2.81	60	1.35	217	3,508	2.90	630	1.08	1,796	1.26	10.46	8.28
Yunnan	3,173	3.21	84	1.89	266	3,990	3.29	1,207	2.07	3,024	1.26	14.32	11.39
Tibet	185	0.19	-	-	-	240	0.20	56	0.10	2,333	1.30	-	-
Shaanxi	2,831	2.87	95	2.13	336	3,514	2.90	1,000	1.72	2,846	1.24	10.50	8.46
Gansu	1,918	1.94	74	1.65	385	2,438	2.01	553	0.95	2,270	1.27	7.49	5.89
Qinghai	377	0.38	18	0.40	472	481	0.40	165	0.28	3,437	1.28	9.29	7.28
Ningxia	374	0.38	15	0.34	403	513	0.42	170	0.29	3,309	1.37	11.25	8.20
Xinjiang	1,283	1.30	53	1.18	410	1,661	1.37	835	1.43	5,025	1.29	15.86	12.25
National	98,705	100.00	4,470	100.00	453	121,121	100.00	58,261	100.00	4,810	1.23	13.03	10.62

Data Source: China Statistical Yearbook (China Statistical Publishing House)

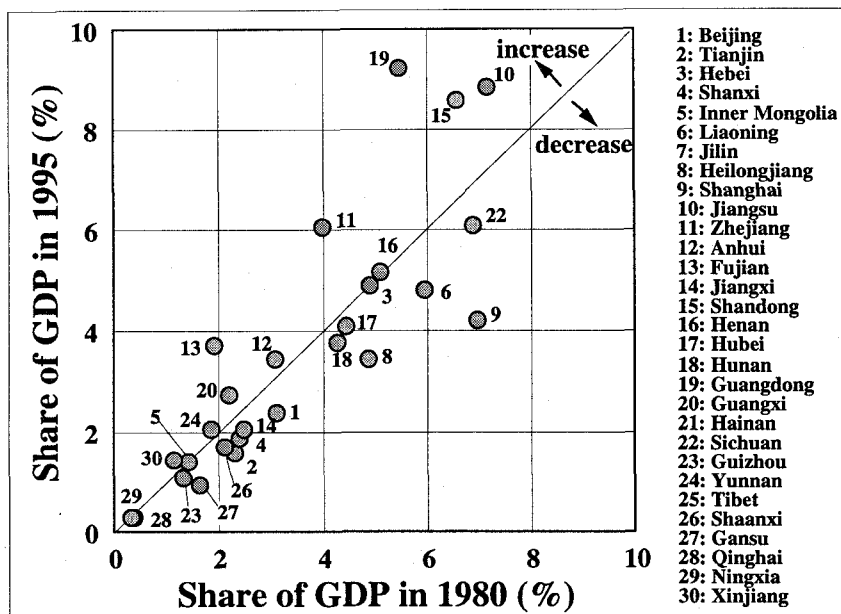The absolute figures of GDP in this table are calculated at current price.

Figure 1. Comparison of regional shares of GDP between in 1980 and in 1995.

Fujian, Zhejiang and Guangdong.

2.2   Regional Characteristics of Industrial Structure

Table 2 shows the change in the gross output value of industry by province between 1981 and 1995. Here, the industrial sector includes not only manufacturing industries but also mining, electric utility, and steam and hot water supply sectors. It consists of different types of enterprises: state-owned, collective-owned and individual-owned. In 1981, Shanghai, Jiangsu and Liaoning were the three largest regions in terms of industrial output. In 1995, however, they were replaced by Jiangsu, Guangdong and Shandong. Figure 3 demonstrates that the share for Jiangsu, Zhejiang, Shandong and Guangdong in the national gross output value of industry has achieved a remarkable rise, while that of Liaoning and Shanghai has dropped.

2.3   Industrial Production by Province and Industrial Sector

Table 3 shows the industrial output values of the provinces by industrial sector. It also indicates shares in the national output by province and industrial sector. Here, we should note the data discrepancy arising from China's statistical system: the gross output values of industry in the China Industrial Economic Statistical Yearbook differ considerably from those in the China Statistical Yearbook. The national gross industrial output value in 1994 was 5,135 billion yuan according to the former, while it was 7,018 billion yuan according to the latter. This discrepancy was due to the different samples used in the two surveys. We use the
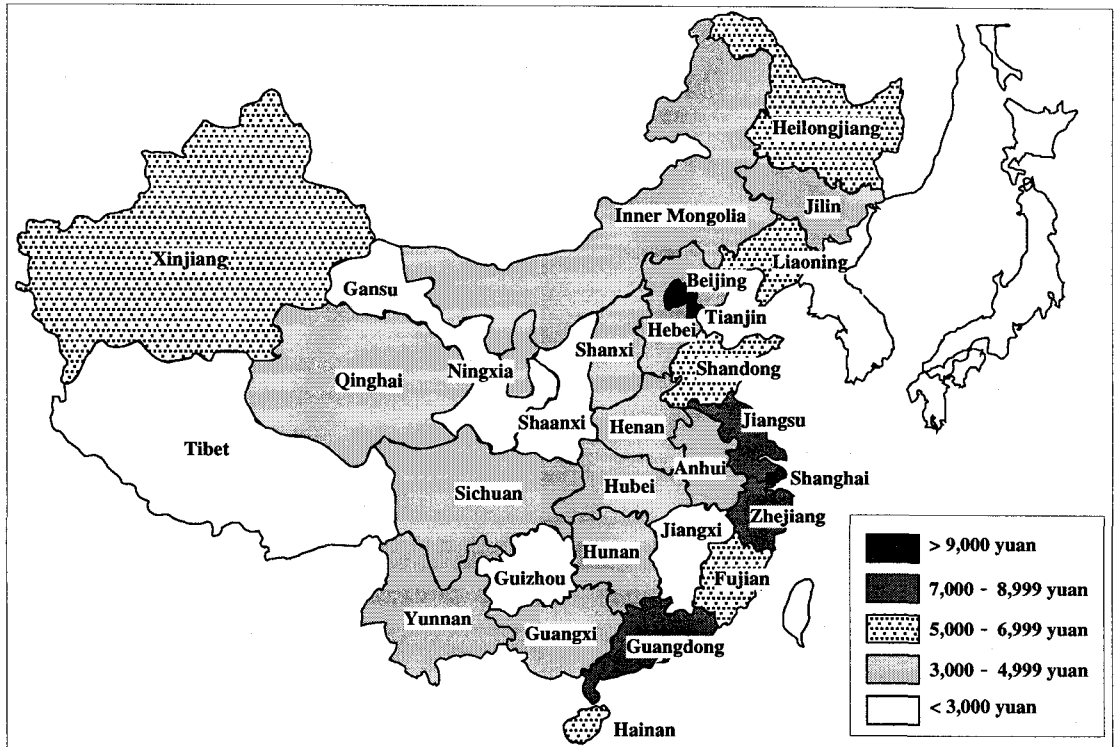
Figure 2. Outline of regional GDP per capita in 1995.

data from China Industrial Economic Statistical Yearbook, as we are interested in the shares by province and industrial sector rather than their values, and no such data were available in the China Statistical Yearbook.

For each industrial sector, the provinces which have a significantly large share in the national output are indicated by their figures put in the box. Among the provinces and industrial sectors, "machine building, electric machinery and electronics equipment manufacturing" in Jiangsu, Guangdong province and Shanghai municipakity and "textile industry" in Jiangsu province are most attractive. Large regional differences are found with the regional shares for industries such as textile and the chemical fiber industries in which it exceeds 50% of the whole when it is summed up to the upper the 3rd regions; for these sectors, in particular, the share for Jiangsu province is more than a quarter of the national total output. On the other hand, the differences in the shares are not large for "food, beverage and tobacco processing" and "production and supply of electric power, steam and hot water" if we take into account the population size of the regions. The industrial output of Jiangsu province is the largest in the country, and it is highly ranked in many industrial sectors. Shandong and Guangdong provinces also retain a higher ranking for many industrial sectors, and Shanghai and Zhejiang are also ranked high for several sectors. For other industrial sectors, "petroleum processing"

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Table 2. Change of regional gross output value of industry.

Region	1981 (100 million yuan)	(%)	1995 (100 million yuan)	(%)	1995/1980 (-)
Beijing	216.61	4.18	1,908.62	2.08	8.81
Tianjin	199.49	3.85	2,094.01	2.28	10.50
Hebei	217.65	4.20	3,995.72	4.35	18.36
Shanxi	118.64	2.29	1,735.58	1.89	14.63
Inner Mongolia	59.68	1.15	781.73	0.85	13.10
Liaoning	451.36	8.72	4,974.90	5.41	11.02
Jilin	133.90	2.59	1,428.96	1.56	10.67
Heilongjiang	250.60	4.84	2,203.78	2.40	8.79
Shanghai	608.70	11.76	5,128.97	5.58	8.43
Jiangsu	465.69	8.99	11,812.86	12.85	25.37
Zhejiang	213.67	4.13	8,087.75	8.80	37.85
Anhui	129.96	2.51	3,155.88	3.43	24.28
Fujian	81.81	1.58	2,800.68	3.05	34.23
Jiangxi	91.69	1.77	1,291.37	1.41	14.08
Shandong	343.62	6.64	8,456.32	9.20	24.61
Henan	203.57	3.93	4,715.11	5.13	23.16
Hubei	246.59	4.76	4,102.58	4.46	16.64
Hunan	176.25	3.40	2,451.47	2.67	13.91
Guangdong	250.36	4.84	9,535.42	10.38	38.09
Guangxi	81.61	1.58	1,666.10	1.81	20.42
Hainan	-	0.00	193.26	0.21	-
Sichuan	275.33	5.32	4,426.37	4.82	16.08
Guizhou	43.81	0.85	557.14	0.61	12.72
Yunnan	70.86	1.37	1,206.55	1.31	17.03
Tibet	1.14	0.02	8.99	0.01	7.89
Shaanxi	105.29	2.03	1,182.72	1.29	11.23
Gansu	74.44	1.44	824.73	0.90	11.08
Qinghai	11.82	0.23	148.64	0.16	12.58
Ningxia	12.37	0.24	197.50	0.21	15.97
Xinjiang	41.16	0.79	802.02	0.87	19.49
National	5,177.67	100.00	91,893.75	100.00	17.75

Data Source: China Statistical Yearbook (China Statistical Publishing House)

and "smelting and processing of ferrous metals" in Liaoning province, and "mining industry" in Heilongjiang province are notable.

The above indicates the regional characteristics of the industrial structure. In China, the formation of an Economic Sphere, consisting of several industries such as heavy, light and resources, has been traditionally formed (World Bank, 1994). Major industries such as iron and steel, cement, chemistry and machinery are scattered around the country, and many small-scale factories have existed in each region. This causes environmental pollution because of the inefficiency of measures for environmental pollution control (Ueta, 1995). However, partial development has recently appeared in branches such as "machine building, electric machinery and electronic equipment manufacturing", "textile industry" and "chemical fiber industry" in connection with overseas investment.

Table 3. Regional views of gross output value (100 million yuan) and composition ratio (%) of industry in 1994.

Region	Mining Industry	Food, Beverage & Tabaco Processing	Texitile Industry	Leather, Furs & Related Products	Papermaking & Paper Products	Printing Industry	Production & Supply of Elcetric Power, Steam & Hot Water	Petroleum Processing	Chemical Industry	Medical & Pharmaceutical Industry
Beijing	11.83	119.42	77.52	14.42	12.31	27.22	44.14	115.63	89.27	21.45
Tianjin	65.37	100.76	88.37	18.91	15.77	6.32	36.03	66.19	102.48	25.21
Hebei	197.29	150.34	193.21	19.69	37.21	14.48	116.09	61.64	135.19	47.31
Shanxi	216.50	46.60	34.74	2.35	5.37	4.78	78.29	26.01	67.90	10.49
Inner Mongolia	57.30	66.33	38.82	4.24	5.03	2.49	49.73	13.69	19.43	6.02
Liaoning	250.43	192.51	129.57	20.14	32.86	15.37	136.09	325.48	194.99	56.03
Jilin	64.56	109.13	27.21	3.96	19.23	7.00	62.70	20.12	134.30	28.01
Heilongjiang	512.12	165.75	45.53	5.72	20.51	6.45	85.07	155.18	38.36	25.12
Shanghai	0.30	185.05	313.50	48.04	30.71	25.39	120.68	81.60	221.86	66.09
Jiangsu	87.89	394.34	1,249.61	97.56	51.04	40.24	170.91	110.56	516.54	91.65
Zhejiang	30.44	248.59	752.25	112.77	50.29	25.75	84.92	71.23	153.00	50.03
Anhui	101.37	255.97	151.89	20.94	26.35	11.09	56.68	40.63	88.17	22.17
Fujian	24.19	180.54	53.97	81.74	41.69	13.81	57.68	26.67	64.35	14.69
Jiangxi	70.18	100.79	56.41	17.00	15.12	8.08	35.76	30.24	43.77	29.51
Shandong	462.29	665.95	510.08	89.87	99.51	34.15	157.26	240.17	299.18	58.32
Henan	200.43	282.46	172.13	36.80	39.01	14.71	105.08	55.24	131.28	40.00
Hubei	72.45	207.85	225.11	18.50	27.56	17.56	84.58	65.64	121.26	31.38
Hunan	71.03	188.32	67.85	15.37	29.41	15.26	59.87	75.11	94.45	15.32
Guangdong	71.98	515.46	366.24	166.27	104.58	54.67	363.92	165.52	238.52	125.55
Guangxi	52.36	191.57	40.09	7.10	20.89	7.78	35.49	6.50	53.07	19.14
Hainan	5.99	42.10	1.81	1.31	1.29	0.91	10.71	0.00	2.78	4.29
Sichuan	132.31	284.36	163.16	25.22	38.75	18.28	87.08	3.87	162.48	39.89
Guizhou	23.67	71.92	9.54	0.90	3.35	3.74	26.77	0.52	26.29	4.23
Yunnan	40.96	365.71	15.47	1.87	9.12	13.49	34.56	0.26	50.85	7.07
Tibet	0.87	0.61	0.24	0.12	0.00	0.15	1.22	0.00	0.01	0.01
Shaanxi	48.03	73.75	76.34	4.00	11.09	9.45	46.16	19.34	35.71	24.10
Gansu	68.70	38.12	15.81	3.16	3.29	2.56	44.73	61.82	49.44	6.24
Qinghai	25.97	8.79	4.97	1.28	0.30	0.44	8.33	0.23	5.84	1.18
Ningxia	15.88	9.04	3.43	0.33	2.97	0.63	15.28	9.23	13.75	1.14
Xinjiang	170.31	51.00	65.07	3.83	4.10	2.33	16.80	32.07	10.83	2.94
National	3,153.00	5,314.00	4,949.93	843.41	758.70	404.59	2,233.18	1,880.37	3,165.33	874.56
Beijing	0.38	2.25	1.57	1.71	1.62	6.73	1.98	6.15	2.82	2.45
Tianjin	2.07	1.90	1.79	2.24	2.08	1.56	1.61	3.52	3.24	2.88
Hebei	6.26	2.83	3.90	2.33	4.90	3.58	5.20	3.28	4.27	5.41
Shanxi	6.87	0.88	0.70	0.28	0.71	1.18	3.51	1.38	2.15	1.20
Inner Mongolia	1.82	1.25	0.78	0.50	0.66	0.62	2.23	0.73	0.61	0.69
Liaoning	7.94	3.62	2.62	2.39	4.33	3.80	6.09	17.31	6.16	6.41
Jilin	2.05	2.05	0.55	0.47	2.53	1.73	2.81	1.07	4.24	3.20
Heilongjiang	16.24	3.12	0.92	0.68	2.70	1.59	3.81	8.25	1.21	2.87
Shanghai	0.01	3.48	6.33	5.70	4.05	6.28	5.40	4.34	7.01	7.56
Jiangsu	2.79	7.42	25.25	11.57	6.73	9.95	7.65	5.88	16.32	10.48
Zhejiang	0.97	4.68	15.20	13.37	6.63	6.36	3.80	3.79	4.83	5.72
Anhui	3.22	4.82	3.07	2.48	3.47	2.74	2.54	2.16	2.79	2.53
Fujian	0.77	3.40	1.09	9.69	5.49	3.41	2.58	1.42	2.03	1.68
Jiangxi	2.23	1.90	1.14	2.02	1.99	2.00	1.60	1.61	1.38	3.37
Shandong	14.66	12.53	10.30	10.66	13.12	8.44	7.04	12.77	9.45	6.67
Henan	6.36	5.32	3.48	4.36	5.14	3.64	4.71	2.94	4.15	4.57
Hubei	2.30	3.91	4.55	2.19	3.63	4.34	3.79	3.49	3.83	3.59
Hunan	2.25	3.54	1.37	1.82	3.88	3.77	2.68	3.99	2.98	1.75
Guangdong	2.28	9.70	7.40	19.71	13.78	13.51	16.30	8.80	7.54	14.36
Guangxi	1.66	3.61	0.81	0.84	2.75	1.92	1.59	0.35	1.68	2.19
Hainan	0.19	0.79	0.04	0.16	0.17	0.22	0.48	0.00	0.09	0.49
Sichuan	4.20	5.35	3.30	2.99	5.11	4.52	3.90	0.21	5.13	4.56
Guizhou	0.75	1.35	0.19	0.11	0.44	0.92	1.20	0.03	0.83	0.48
Yunnan	1.30	6.88	0.31	0.22	1.20	3.33	1.55	0.01	1.61	0.81
Tibet	0.03	0.01	0.00	0.01	0.00	0.04	0.05	0.00	0.00	0.00
Shaanxi	1.52	1.39	1.54	0.47	1.46	2.34	2.07	1.03	1.13	2.76
Gansu	2.18	0.72	0.32	0.37	0.43	0.63	2.00	3.29	1.56	0.71
Qinghai	0.82	0.17	0.10	0.15	0.04	0.11	0.37	0.01	0.18	0.13
Ningxia	0.50	0.17	0.07	0.04	0.39	0.16	0.68	0.49	0.43	0.13
Xinjiang	5.40	0.96	1.31	0.45	0.54	0.58	0.75	1.71	0.34	0.34
National	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Data Source: China Industrial Economic Statistical Yearbook 1995 (China Statistical Publishing House)

Table 3. (continued) Regional views of gross output value (100 million yuan) and composition ratio (%) of industry in 1994.

Region	Chemical Fiber Industry	Rubber Products	Plastic Products	Building Materials & Other Nonmetal Minerals	Smelting & Pressing of Ferrous Metals	Smelting & Pressing of Nonferrous Metals	Metal Products	Machine Building, Electric Machinery & Electronic Equipment Manufacturing	Other Industries	Total
Beijing	5.11	7.05	17.36	79.87	233.96	12.70	53.98	482.16	123.64	1,549.04
Tianjin	7.96	14.63	17.64	26.31	145.45	27.99	66.86	377.27	84.87	1,294.39
Hebei	16.62	20.22	25.33	151.23	330.14	19.84	78.60	305.12	74.05	1,993.60
Shanxi	5.78	9.28	5.11	36.94	148.48	27.26	25.81	105.43	13.05	870.17
Inner Mongolia	1.04	1.46	1.97	27.34	93.09	24.54	12.11	41.03	34.66	500.32
Liaoning	17.99	33.97	32.86	161.86	546.55	100.30	109.91	716.31	102.61	3,175.83
Jilin	13.99	6.74	12.12	50.27	53.38	13.99	20.06	348.60	60.18	1,055.55
Heilongjiang	9.57	15.47	12.62	51.17	54.99	9.90	27.53	199.05	111.07	1,551.18
Shanghai	123.54	55.97	39.80	84.95	579.51	81.11	131.87	1,229.86	244.74	3,664.57
Jiangsu	166.69	55.46	146.03	331.43	346.89	129.65	287.99	1,800.05	476.37	6,550.90
Zhejiang	56.56	34.67	121.07	183.97	83.80	71.07	117.84	771.78	341.71	3,361.74
Anhui	6.99	16.38	28.15	117.71	119.58	38.49	37.15	276.73	76.57	1,493.01
Fujian	11.75	18.09	48.46	84.18	35.31	11.54	28.07	269.78	195.34	1,261.85
Jiangxi	13.03	4.91	9.74	75.28	62.13	42.61	18.09	187.70	61.13	881.48
Shandong	46.98	99.88	90.95	389.90	177.39	39.76	172.63	953.13	291.86	4,879.26
Henan	12.33	22.46	20.76	158.19	101.84	58.38	36.22	378.50	55.40	1,921.22
Hubei	11.84	20.89	26.32	122.67	284.39	37.23	65.28	506.31	111.28	2,058.10
Hunan	6.60	12.61	12.23	116.94	93.45	64.51	31.76	276.11	50.26	1,296.46
Guangdong	63.66	42.12	178.86	356.71	106.32	67.11	215.22	1,557.44	564.85	5,325.00
Guangxi	7.08	9.97	10.63	86.73	40.88	31.08	17.95	205.34	37.48	881.13
Hainan	1.83	2.81	1.79	8.06	2.02	0.34	1.87	23.26	4.73	117.90
Sichuan	19.70	10.31	43.31	149.29	314.75	44.07	77.07	559.66	62.98	2,236.54
Guizhou	1.26	10.05	3.28	19.32	23.04	37.68	24.51	75.19	6.42	371.68
Yunnan	3.15	6.65	4.55	30.82	53.18	57.83	9.56	86.58	14.24	805.92
Tibet	0.00	0.00	0.00	1.04	0.00	0.03	0.01	0.27	0.93	5.51
Shaanxi	2.90	4.12	4.33	37.24	37.21	13.56	17.46	268.99	23.87	757.65
Gansu	2.19	2.11	4.11	27.91	42.03	101.89	10.81	64.03	12.30	561.25
Qinghai	0.00	0.16	0.46	3.43	21.21	18.12	2.81	12.99	2.23	118.74
Ningxia	0.52	8.58	1.31	6.24	9.99	12.98	2.37	19.89	2.16	135.72
Xinjiang	0.61	3.11	5.46	20.16	24.46	6.78	6.60	22.80	6.55	455.81
National	637.25	550.13	926.64	2,997.15	4,165.42	1,202.36	1,707.99	12,121.39	3,247.48	51,132.88
Beijing	0.80	1.28	1.87	2.66	5.62	1.06	3.16	3.98	3.81	3.03
Tianjin	1.25	2.66	1.90	0.88	3.49	2.33	3.91	3.11	2.61	2.53
Hebei	2.61	3.68	2.73	5.05	7.93	1.65	4.60	2.52	2.28	3.90
Shanxi	0.91	1.69	0.55	1.23	3.56	2.27	1.51	0.87	0.40	1.70
Inner Mongolia	0.16	0.27	0.21	0.91	2.23	2.04	0.71	0.34	1.07	0.98
Liaoning	2.82	6.17	3.55	5.40	13.12	8.34	6.44	5.91	3.16	6.21
Jilin	2.20	1.23	1.31	1.68	1.28	1.16	1.17	2.88	1.85	2.06
Heilongjiang	1.50	2.81	1.36	1.71	1.32	0.82	1.61	1.64	3.42	3.03
Shanghai	19.39	10.17	4.30	2.83	13.91	6.75	7.72	10.15	7.54	7.17
Jiangsu	26.16	10.08	15.76	11.06	8.33	10.78	16.86	14.85	14.67	12.81
Zhejiang	8.88	6.30	13.07	6.14	2.01	5.91	6.90	6.37	10.52	6.57
Anhui	1.10	2.98	3.04	3.93	2.87	3.20	2.18	2.28	2.36	2.92
Fujian	1.84	3.29	5.23	2.81	0.85	0.96	1.64	2.23	6.02	2.47
Jiangxi	2.04	0.89	1.05	2.51	1.49	3.54	1.06	1.55	1.88	1.72
Shandong	7.37	18.16	9.82	13.01	4.26	3.31	10.11	7.86	8.99	9.54
Henan	1.93	4.08	2.24	5.28	2.44	4.86	2.12	3.12	1.71	3.76
Hubei	1.86	3.80	2.84	4.09	6.83	3.10	3.82	4.18	3.43	4.03
Hunan	1.04	2.29	1.32	3.90	2.24	5.37	1.86	2.28	1.55	2.54
Guangdong	9.99	7.66	19.30	11.90	2.55	5.58	12.60	12.85	17.39	10.41
Guangxi	1.11	1.81	1.15	2.89	0.98	2.58	1.05	1.69	1.15	1.72
Hainan	0.29	0.51	0.19	0.27	0.05	0.03	0.11	0.19	0.15	0.23
Sichuan	3.09	1.87	4.67	4.98	7.56	3.67	4.51	4.62	1.94	4.37
Guizhou	0.20	1.83	0.35	0.64	0.55	3.13	1.44	0.62	0.20	0.73
Yunnan	0.49	1.21	0.49	1.03	1.28	4.81	0.56	0.71	0.44	1.58
Tibet	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03	0.01
Shaanxi	0.46	0.75	0.47	1.24	0.89	1.13	1.02	2.22	0.74	1.48
Gansu	0.34	0.38	0.44	0.93	1.01	8.47	0.63	0.53	0.38	1.10
Qinghai	0.00	0.03	0.05	0.11	0.51	1.51	0.16	0.11	0.07	0.23
Ningxia	0.08	1.56	0.14	0.21	0.24	1.08	0.14	0.16	0.07	0.27
Xinjiang	0.10	0.57	0.59	0.67	0.59	0.56	0.39	0.19	0.20	0.89
National	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
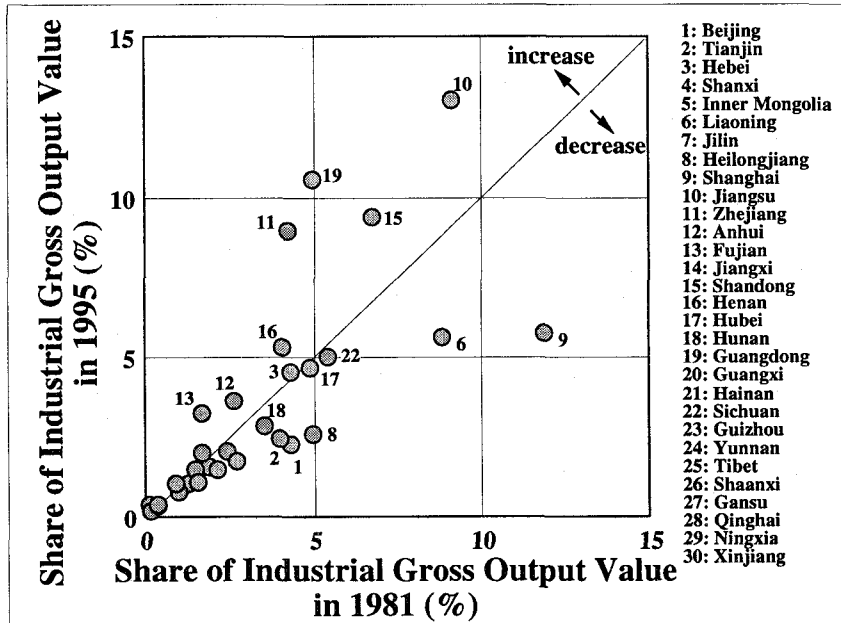
Figure 3. Comparison of regional share of gross output value of industry between in 1981 and in 1995.

3.   Characteristics of Environmental Loading

3.1   An Overview

In China, environmental pollutants are mainly divided into three substances, waste water, waste gas and waste residue, whose discharged and emitted volume has been mounting through out the country every year. Figures 4, 5 and 6 demonstrate the temporal changes of waste water discharged, the volume of waste gas emissions, and the industrial waste residue produced, respectively.

In Figure 4, it is known that the total waste water discharged gradually increases year by year. On the contrary, industrial waste water discharged has decreased since 1987. Here, the difference of total and industrial waste water discharged represents domestic sewage, which increases contrary to industrial sewage. By the way, there is a discontinuity of the volume of treated industrial waste water between 1990 and 1991. It refers to the volume of industrial waste water after being treated and purified through various water treatment facilities in the reference period, including the volume discharged or recovered after being treated. Since 1991, if there are treatment facilities both at the outlets of workshops and at the outlets of the factory, and the same volume of waste water has been treated twice, duplication should be avoided in the calculation of the volume of treated industrial waste water (State Statistical Bureau, People's Republic of China, 1997).

Figure 5 shows the continuous increase in the total volume of waste gas emissions, and in the volume of industrial waste gas emissions which has been present since 1991.
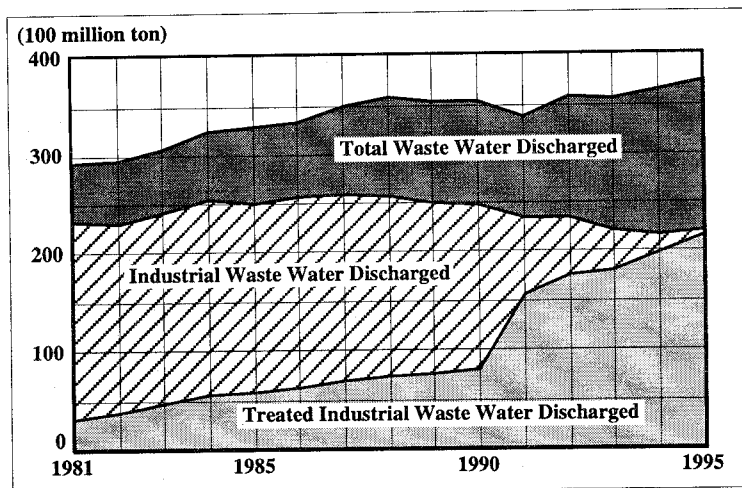
Figure 4. Temporal change of waste water discharged.
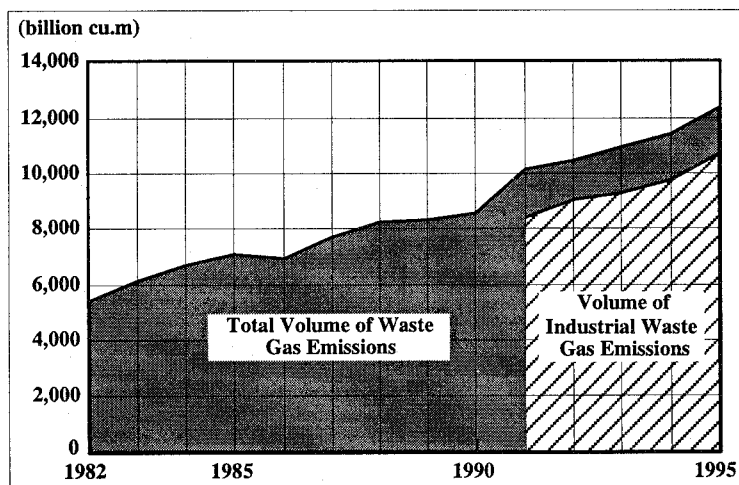
Figure 5. Temporal change of waste gas emissions.

The industrial waste residue produced refers to the total amount of solid, semi-solid or high concentrated liquid residue produced by industrial enterprises in their production process, including residue from melting, slag, powdered coal ash, gangue, chemical residue, tailings, radioactive residue and other residues, but excluding stripped or dug stones in coal mining. Industrial waste residue used refers to solids residue used as fertilizers, building materials, materials for making fields and roads, or for other purpose. Statistics on the utilization of industrial waste residue are to be collected by residue-producing units. The industrial waste
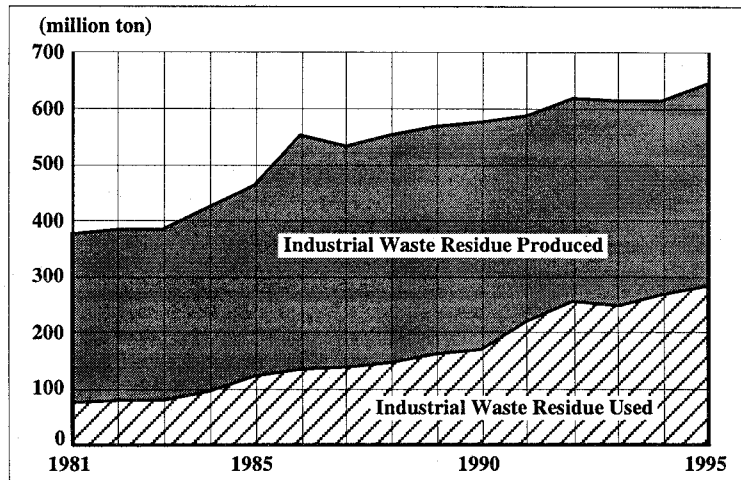
Figure 6. Temporal change of waste residue produced.

residue produced has gradually increased, and also the industrial waste residue used has been increasing as shown in Figure 6. It is a pity that the statistics on domestic waste residue are not collected.

3.2 Regional Characteristics of Environmental Loading

The amount of waste water, waste gas and waste residue is reported in the China Environmental Statistics Databook in 1981-1990 and in the China Environment Yearbooks which have been published each year since 1990. The changes by regions are shown in Table 4.

In total waste water discharged, the municipality of Shanghai and the provinces of Hubei and Guangdong have greatly increased, but the increases are not large in the provinces of Liaoning, Jiangsu and Sichuan. The provinces which had large waste water discharged amounts in 1995 are Guangdong (9.4%), Hubei (8.1%) and Sichuan (8.0%). The provinces of Liaoning, Shandong and Hebei had a large volume of waste gas emissions in 1995, and in the changes for 1982 to 1995, Shandong and Hebei expanded to 2.6 (=9,176/3,492) and 2.3 (=8,085/3,467) times respectively in contrast to Liaoning's 1.4 (=9,686/6,821) times. The provinces which produced large amounts of industrial waste residue in 1995 are Liaoning (10.7%) and Hebei (9.6%). In Liaoning, in spite of the decrease in industrial waste residue produced since 1981, the highest ratio of industrial waste residue produced in the country was obtained in 1995.

3.3 Environmental Loading from Industries

Table 5 shows the changes of environmental loading from industries. The branches of industry which have large amounts of industrial waste water discharged are "the chemical industry", "the smelting and pressing of ferrous metal industry" and "the papermaking and paper products industry". In their temporal changes, the chemical industry has been on the decrease, the smelting and pressing of ferrous metal industry is not changing, and the

Table 4. Change of environmental loading in regions.

Region	Total Waste Water Discharged (10,000 ton)					Total Volume of Waste Gas Emissions (100 million cu.m)				
	1981	1986	1991	1995	(%)	1982	1986	1991	1995	(%)
Beijing	71,089	83,891	84,170	96,150	2.58	2,021	2,534	3,062	3,360	2.72
Tianjin	37,613	41,343	42,560	65,000	1.74	952	1,173	1,501	1,905	1.54
Hebei	135,983	125,977	116,164	122,941	3.30	3,467	4,073	6,191	8,085	6.55
Shanxi	54,577	61,488	59,428	58,361	1.57	2,123	2,813	5,005	6,253	5.07
Inner Mongolia	38,662	33,869	42,038	41,990	1.13	1,549	2,016	3,987	4,080	3.31
Liaoning	200,642	212,109	211,106	221,022	5.93	6,821	7,655	8,958	9,686	7.85
Jilin	74,921	83,684	88,097	78,884	2.12	1,932	2,412	3,704	4,434	3.59
Heilongjiang	84,263	145,044	125,256	128,717	3.45	4,178	4,242	5,144	5,451	4.42
Shanghai	179,050	194,311	195,808	224,515	6.02	2,440	3,076	4,617	5,095	4.13
Jiangsu	209,295	258,614	293,954	221,575	5.94	2,828	4,431	6,555	6,065	4.91
Zhejiang	101,959	136,126	135,284	173,589	4.66	1,147	2,291	4,676	3,569	2.89
Anhui	90,746	122,035	129,312	141,032	3.78	1,699	2,723	2,685	4,365	3.54
Fujian	66,587	82,443	91,444	104,854	2.81	-	934	1,589	2,545	2.06
Jiangxi	104,633	102,404	99,185	106,124	2.85	953	1,425	1,816	2,645	2.14
Shandong	104,790	127,277	137,051	158,681	4.26	3,492	4,814	7,148	9,176	7.44
Henan	142,659	143,797	146,660	169,312	4.54	4,158	2,969	4,626	7,316	5.93
Hubei	177,577	228,551	265,510	300,598	8.06	1,718	2,443	3,892	4,485	3.63
Hunan	194,719	226,084	204,773	167,553	4.49	2,500	2,270	2,919	3,607	2.92
Guangdong	194,275	213,187	251,090	348,937	9.36	1,455	2,336	4,615	6,636	5.38
Guangxi	141,131	110,591	139,949	160,135	4.29	894	1,104	1,617	2,887	2.34
Hainan	-	13,166	17,572	20,199	0.54	-	69	117	184	0.15
Sichuan	269,679	324,765	228,061	296,840	7.96	3,111	3,980	5,819	7,230	5.86
Guizhou	61,607	60,420	47,081	43,608	1.17	1,012	1,226	2,481	2,550	2.07
Yunnan	43,000	54,019	59,800	86,067	2.31	-	1,343	1,537	2,107	1.71
Tibet	-	187	795	4,200	0.11	-	5	8	18	0.01
Shaanxi	58,440	61,883	58,120	76,897	2.06	1,194	1,581	2,094	2,819	2.28
Gansu	41,953	45,625	46,905	48,094	1.29	2,019	1,816	2,300	2,807	2.27
Qinghai	12,240	12,764	9,615	9,440	0.25	16	329	382	507	0.41
Ningxia	8,159	9,866	10,414	13,366	0.36	252	391	898	1,085	0.88
Xinjiang	14,894	19,310	25,087	39,827	1.07	482	863	1,472	2,400	1.94
National	2,917,873	3,334,830	3,362,054	3,728,508	100.00	54,412	69,336	101,415	123,407	100.00

Region	Industrial Waste Residue Produced (10,000 ton)				
	1981	1986	1991	1995	(%)
Beijing	653	784	701	1,068	1.66
Tianjin	334	370	398	544	0.84
Hebei	2,687	5,538	5,327	6,186	9.59
Shanxi		2,865	3,687	4,204	6.52
Inner Mongolia	758	1,607	1,997	2,270	3.52
Liaoning	7,264	7,336	6,959	6,920	10.73
Jilin	1,314	1,438	1,601	1,672	2.59
Heilongjiang	1,631	3,516	3,780	2,681	4.16
Shanghai	663	883	1,090	1,368	2.12
Jiangsu	1,137	1,850	2,366	2,883	4.47
Zhejiang	463	845	888	1,030	1.60
Anhui	1,404	2,553	2,416	2,749	4.26
Fujian	270	689	710	728	1.13
Jiangxi	1,448	3,444	2,984	3,669	5.69
Shandong	2,522	2,860	3,837	4,484	6.95
Henan	1,463	2,066	2,290	2,792	4.33
Hubei	1,122	1,764	1,844	2,063	3.20
Hunan	1,975	2,269	2,033	1,853	2.87
Guangdong	1,250	1,578	1,784	1,465	2.27
Guangxi	885	1,149	1,312	1,503	2.33
Hainan	-	93	128	87	0.13
Sichuan	3,697	3,928	3,941	4,290	6.65
Guizhou	764	894	994	1,309	2.03
Yunnan	1,638	1,894	1,902	2,147	3.33
Tibet	-	-	-	0	0.00
Shaanxi	906	1,367	1,374	1,870	2.90
Gansu	858	895	1,401	1,432	2.22
Qinghai	50	180	280	208	0.32
Ningxia	269	248	335	397	0.62
Xinjiang	239	492	399	602	0.93
National	37,664	55,395	58,759	64,474	100.00

Data Source: China Environmental Statistics Databook in 1981-1990 (China Environmental Science Publishing Company, 1994); China Environment Yearbook (China Environment Yearbook Publishing Company)

Table 5. Change of environmental loading in industries.

Branch of Industry	Industrial Waste Water Discharged (million ton)						Total Volume of Industrial Waste Gas Emissions (100 million cu.m)					
	1991	1992	1993	1994	1995	(%)	1991	1992	1993	1994	1995	(%)
Mining Industry	1,710	1,718	1,487	1,405	1,439	6.49	3,438	3,871	3,518	3,287	3,376	3.14
Food, Beverage & Tabacco Processing	1,998	2,037	1,927	1,715	1,781	8.03	2,828	2,961	2,832	2,674	2,949	2.74
Textile Industry	1,404	1,385	1,294	1220	1,164	5.25	2,139	1,814	1,800	1,815	1,633	1.52
Leather, Furs & Related Products	63	67	60	59	58	0.26	112	90	99	76	99	0.09
Papermaking & Paper Products	2,187	2,241	2,158	2183	2,390	10.77	2,084	2,487	1,731	1,622	1,939	1.80
Printing Industry	34	30	31	29	29	0.13	85	71	58	68	74	0.07
Production & Supply of Electric Power, Steam & Hot Water	2,103	2,158	2,127	2,081	2,094	9.44	26,962	28,531	32,264	34,854	38,175	35.52
Petroleum Processing	341	372	371	375	465	2.10	1,300	1,490	1,577	1,713	2,210	2.06
Coking, Gas & Coal Products	202	259	196	193	191	0.86	523	797	975	872	737	0.69
Chemical Industry	5,983	5,552	4,918	4,867	4,852	21.87	7,880	7,740	7,539	7,623	8,570	7.97
Medical and Pharmaceutical Industry	510	495	460	458	453	2.04	700	625	688	709	594	0.55
Chemical Fiber Industry	519	597	576	520	559	2.52	1,857	2,327	2,269	2,219	2,543	2.37
Rubber Products	176	172	172	154	147	0.66	676	604	576	567	569	0.53
Plastic Products	65	67	72	67	60	0.27	188	219	288	205	203	0.19
Building Materials & Other Nonmetal Minerals	579	643	576	610	615	2.77	11,108	12,155	13,002	14,067	14,967	13.93
*Cement Manufacturing	228	184	253	270	280	1.26	7,016	5,303	9,105	10,186	10,753	10.00
Smelting & Pressing of Ferrous Metals	3,053	2,961	3,009	3,046	3,065	13.81	12,199	12,987	14,021	15,141	16,524	15.37
Smelting & Pressing of Nonferrous Metals	442	418	444	507	508	2.29	3,973	3,817	4,271	4,524	6,574	6.12
Metal Products	108	113	105	98	101	0.46	375	447	282	305	308	0.29
Machine Building, Electric Machinery & Electronic Equipment Manufacturing	1,435	1,394	1,367	1,369	1,308	5.89	4,749	4,815	4,220	3,769	3,914	3.64
Other Industries	656	706	601	596	908	4.09	1,558	1,785	1,413	1,355	1,519	1.41
Total	23,566	23,385	21,949	21,551	22,189	100.00	84,734	89,633	93,432	97,463	107,478	100.00

Branch of Industry	Industrial Waste Residue Produced (10,000 ton)					
	1991	1992	1993	1994	1995	(%)
Mining Industry	27,243	28,741	27,531	26,377	26,644	41.33
Food, Beverage & Tabacco Processing	2,203	2,317	2,252	1,900	2,110	3.27
Textile Industry	605	638	548	534	511	0.79
Leather, Furs & Related Products	42	36	35	30	26	0.04
Papermaking & Paper Products	499	558	486	494	546	0.85
Printing Industry	13	12	14	12	15	0.02
Production & Supply of Electric Power, Steam & Hot Water	8,892	9,373	10,252	11,204	12,191	18.91
Petroleum Processing	413	487	351	366	496	0.77
Coking, Gas & Coal Products	426	495	465	366	283	0.44
Chemical Industry	3,777	3,862	3,877	4,098	4,596	7.13
Medical and Pharmaceutical Industry	245	237	210	217	218	0.34
Chemical Fiber Industry	176	245	247	256	262	0.41
Rubber Products	110	113	106	102	107	0.17
Plastic Products	30	27	39	38	39	0.06
Building Materials & Other Nonmetal Minerals	940	1,403	1,104	1,078	1,196	1.86
*Cement Manufacturing	203	418	309	285	377	0.58
Smelting & Pressing of Ferrous Metals	9,213	9,425	10,017	10,812	11,200	17.37
Smelting & Pressing of Nonferrous Metals	2,007	1,935	2,386	2,124	2,477	3.84
Metal Products	130	69	68	69	69	0.11
Machine Building, Electric Machinery & Electronic Equipment Manufacturing	1,226	1,172	1,244	1,082	1,006	1.56
Other Industries	559	739	475	544	482	0.75
Total	58,759	61,884	61,708	61,704	64,474	100.00

Data Source: China Environment Yearbook (China Environment Yearbook Publishing Company)

Table 6. Environmental loading per products in industries.

Branch of Industry	Industrial Waste Water Discharged per Products (ton per yuan)				Total Volume of Industrial Waste Gas Emissions per Product (cu.m per yuan)				Industrial Waste Residue Produced per Products (ton per10,000 yuan)			
	1992	1993	1994	1995	1992	1993	1994	1995	1992	1993	1994	1995
Mining Industry	179	141	122	114	4.03	3.33	2.86	2.68	2,991	2,604	2,295	2,116
Food, Beverage & Tabacco Processing	97	82	69	64	1.41	1.21	1.08	1.06	110	96	77	76
Textile Industry	70	60	55	49	0.91	0.84	0.82	0.69	32	25	24	21
Leather, Furs & Related Products	47	34	28	25	0.63	0.56	0.37	0.43	25	20	14	11
Papermaking & Paper Products	624	601	500	513	6.93	4.82	3.71	4.16	155	135	113	117
Printing Industry	24	21	19	19	0.57	0.40	0.45	0.47	10	10	8	10
Production & Supply of Electric Power, Steam & Hot Water	416	344	305	264	54.97	52.21	51.01	48.14	1,806	1,659	1,640	1,537
Petroleum Processing	60	57	53	60	2.40	2.44	2.40	2.83	79	54	51	64
Coking, Gas & Coal Products	294	211	191	180	9.06	10.47	8.65	6.95	563	500	363	267
Chemical Industry	309	269	239	206	4.31	4.12	3.75	3.63	215	212	202	195
Medical and Pharmaceutical Industry	100	80	70	58	1.26	1.20	1.09	0.76	48	37	33	28
Chemical Fiber Industry	157	134	119	112	6.11	5.29	5.07	5.11	64	58	58	53
Rubber Products	46	43	37	32	1.63	1.46	1.37	1.23	31	27	25	23
Plastic Products	23	18	21	16	0.74	0.73	0.63	0.54	9	10	12	10
Building Materials & Other Nonmetal Minerals	67	59	56	53	12.69	13.28	12.94	12.83	146	113	99	102
Smelting & Pressing of Ferrous Metals	214	181	171	166	9.37	8.42	8.52	8.97	680	601	609	608
Smelting & Pressing of Nonferrous Metals	77	71	80	65	7.04	6.85	7.10	8.45	357	383	333	318
Metal Products	34	29	23	20	1.34	0.77	0.72	0.62	21	19	16	14
Machine Building, Electric Machinery & Electronic Equipment Manufacturing	31	25	21	17	1.08	0.76	0.57	0.50	26	22	16	13
Other Industries	58	47	40	50	1.47	1.11	0.91	0.83	61	37	36	26
Total	130	101	90	81	4.99	4.31	4.06	3.93	345	285	257	236

papermaking and paper products industry has been on the increase. In industrial waste gas emissions, "production and supply of electric power, steam and hot water" represents a great deal of them. The total volume of industrial waste gas emissions in the branches of "smelting and pressing of ferrous metal" and "building materials and other nonmetal minerals" is also large, and their volume has been increasing year by year. "The mining industry" produces the major portion of industrial waste residue, and "the production and supply of electric power, steam and hot water industry" and "the smelting and pressing of ferrous metal industry" also have a large amount which has been increasing in recent years.

Next, the values for environmental loading per product in industries are estimated as shown in Table 6. We used the gross output values of industries entered in the China Environment Yearbook, in which the total value of gross output in industry and the number of enterprises are 2,732 billion yuan and 70,177 units respectively for 1995. These values and numbers in the China Statistic Yearbook are 9,189 billion yuan and 7.34 million units respectively, so there are large differences between them. Taking into consideration that the difference in the gross output values is smaller than that in the numbers of enterprises, it can be said that the enterprises which were used in the Environment Yearbook were on a relatively larger scale. The branches which have large values of environmental loading per product are much the same as the large environmental loading in waste water, waste gas and waste residue. Especially, the values in "production and supply of electric power, steam and hot water" are larger for each waste. One of the reasons is that the prices of electricity, steam and hot water are kept lower by national policy. The values of environmental loading per product show decrease tendencies except for a few branches such as "petroleum processing" and "building materials and other

nonmetal minerals".

4. The Relationship between Industrial Structure and Environmental Loading

4.1 The Relationship between Industrial Products and Environmental Loading

The regional relationships between industrial products and environmental loading are demonstrated in Figure 7, where the shares of industrial gross output value and of industrial waste water discharged, waste gas emissions and waste residue produced are used. The regions which take the points above the diagonal line have a larger amount of environmental loading per industrial products; on the contrary, the regions which take the points below the diagonal line have a smaller amount.

In the case of industrial waste water, the provinces which have a larger amount of waste water discharged per product are Sichuan and Hunan. The provinces in the coastal regions, such as Jiangsu, Zhejiang, Shandong and Guangdong, where industrial products have remarkably extended recently, have a smaller amount of waste water discharged in comparison to the larger industrial product areas. In fact, Jiangsu takes the first position in the amount of waste water discharged. The provinces of Hebei and Liaoning have a larger volume of waste gas emissions per industrial product, whereas the provinces of Jiangsu, Zhejiang, Shandong and Guangdong have a smaller volume. The characteristics for industrial waste residue are similar to those for waste water and waste gas.

Figure 8 shows the relationship between industrial products and environmental loading in the branches of industry. The lines in the figure are binding the point on mean values of each index to the origin, then the branches which take the points above the line have a larger amount of environmental loading per industrial products; on the contrary, the branches which take the points below the line have a smaller amount.

The branches having large values of industrial waste water discharged per industrial gross output value are "the chemical industry", "the smelting and pressing of ferrous metals industry", "the papermaking and paper products industry" and "the production and supply of electric power, steam and hot water industry". "Production and supply of electric power, steam and hot water" is emitting masses of waste gas, and "smelting and pressing of ferrous metals" and "building materials and other nonmetal minerals", which mainly consists of "cement manufacturing", are following. In the case of industrial waste residue, the branches of "mining industry", "production and supply of electric power, steam and hot water industry" and "smelting and pressing of ferrous metals industry" have a larger amount per product. On the other hand, "machine building, electric machinery and electronic equipment manufacturing" is a branch which has a smaller environmental loading per industrial products; in other words, it can be said to be a minor source of direct pollution.

4.2 Environmental Loading from Industry in Each Region

In order to investigate the environmental loading from industry in each region, we attempted to get the amount of waste water, waste gas and waste residue in the regions and in the branches by multiplying the industrial gross output values in each region by the values of environmental loading per product in each branch. The results are shown in Tables 7, 8 and
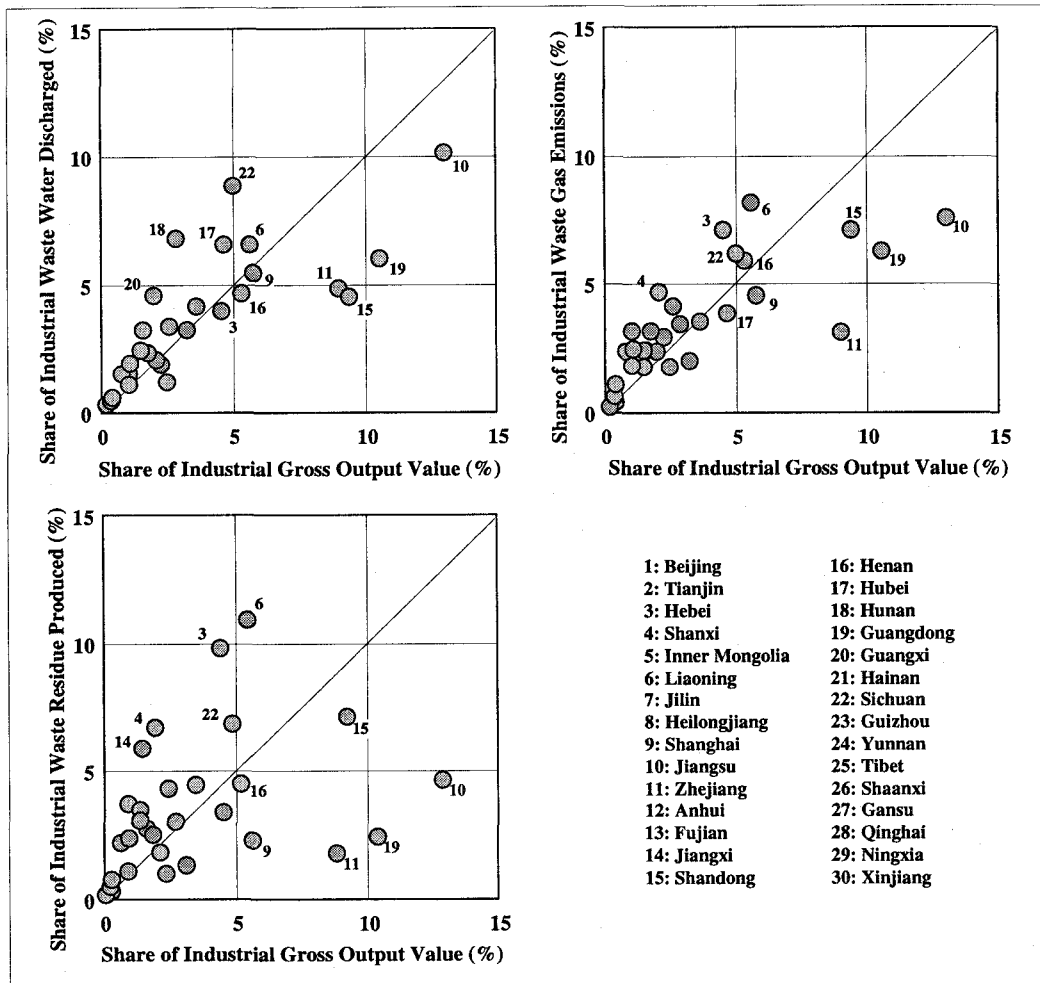
Figure 7. Regional relationship between industrial products and environmental loading in 1995.

9. In these Tables, the sections (regions and branches) marked by squares have a larger value, over 1 percentage of the total value for the nation.

The regions and branches which have larger values of waste water discharged are "the chemical industry" in the provinces of Jiangsu and Shandong, and "the production and supply of electric power, steam and hot water industry" in Guangdong. In the case of waste gas as shown in Table 8, "production and supply ofelectric power, steam and hot water" is emitting masses of waste gas in many regions, and "smelting and pressing of ferrous metals" is emitting waste gas in several regions. Particularly in these cases, they are "the production and supply of electric power, steam and hot water industry" in the provinces of Guangdong, Jiangsu and
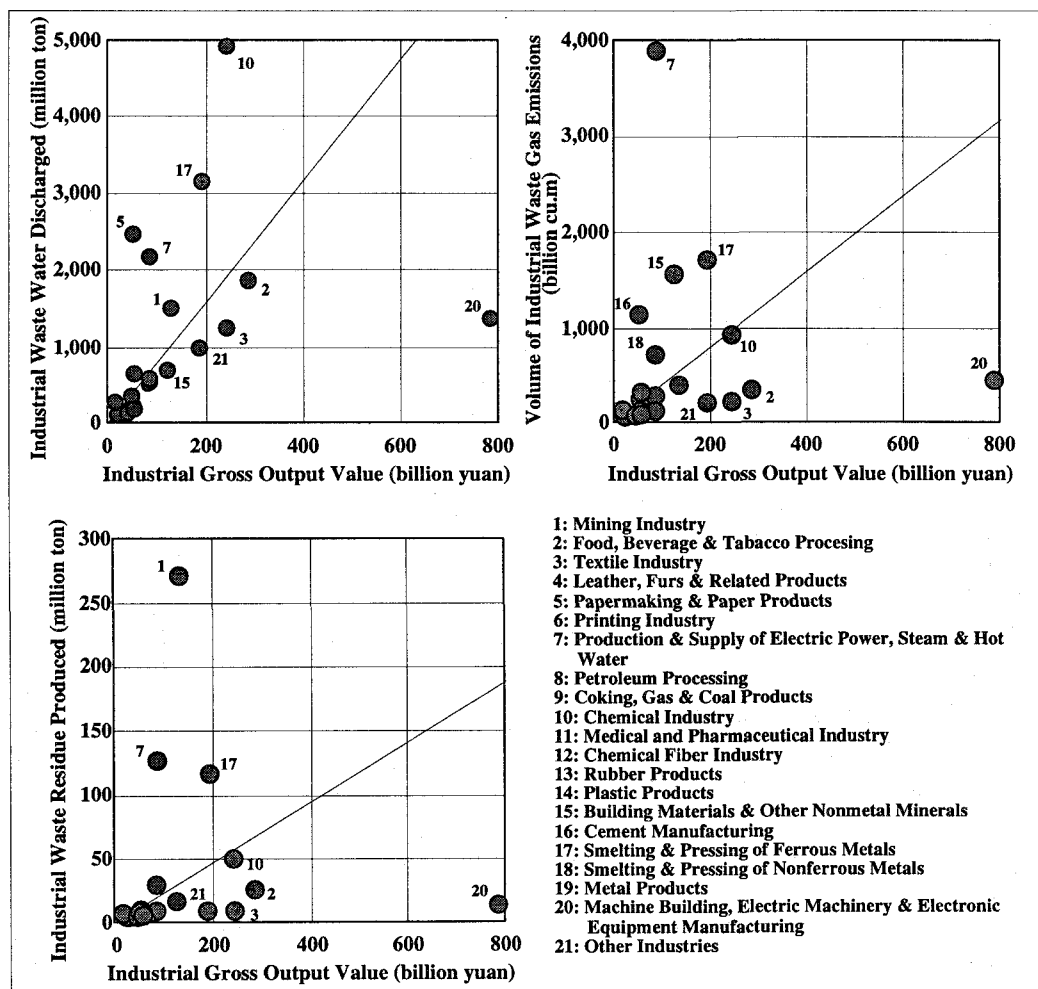
Figure 8. Relationship between industrial products and environmental loading in branches in 1995.

Shandong, and "the smelting and pressing of ferrous metals industry" in the municipality of Shanghai and the province of Liaoning that are emitting masses of waste gas. "The mining industry" in the provinces of Heilongjiang and Shandong, and "the production and supply of electric power, steam and hot water industry" in Guangdong produce waste residue in large quantities.

The total amount of industrial waste water discharged in the nation came to 43.8 billion tons, which is almost two times the value entered in the China Environment Yearbook, that is 21.6 billion tons. This is similar that for waste gas and waste residue.

Table 7. Industrial waste water discharged in regions in 1994.

(unit: million ton)

Region	MI	FBT	TI	LFRP	PPP	PI	PSEP	PeP	CI	MPI	CFI	RP	PIP	BMON	SPFM	SPNM	MP	MBEM	OI	Total
Beijing	14	83	43	4	62	5	134	104	214	51	4	8	6	16	131	22	43	112	26	1,083
Tianjin	80	70	49	5	79	1	110	60	245	60	6	17	7	5	82	48	53	87	18	1,082
Hebei	241	104	106	6	186	3	354	56	324	113	12	24	9	31	185	34	63	71	15	1,936
Shanxi	265	32	19	1	27	1	238	23	163	25	4	11	2	8	83	47	21	24	3	996
Inner Mongolia	70	46	21	1	25	0	151	12	47	14	1	2	1	6	52	42	10	10	7	518
Liaoning	306	133	71	6	164	3	414	294	467	134	13	40	12	33	307	172	87	166	21	2,845
Jilin	79	76	15	1	96	1	191	18	321	67	10	8	5	10	30	24	16	81	13	1,062
Heilongjiang	626	115	25	2	103	1	259	140	92	60	7	18	5	11	31	17	22	46	23	1,602
Shanghai	0	128	173	14	154	5	368	74	531	158	87	66	15	17	325	139	105	285	51	2,695
Jiangsu	107	273	688	28	255	8	521	100	1,236	219	117	66	54	68	195	222	229	417	99	4,904
Zhejiang	37	172	414	32	251	5	259	64	366	120	40	41	45	38	47	122	94	179	71	2,398
Anhui	124	177	84	6	132	2	173	37	211	53	5	19	10	24	67	66	30	64	16	1,300
Fujian	30	125	30	23	208	3	176	24	154	35	8	21	18	17	20	20	22	63	41	1,038
Jiangxi	86	70	31	5	76	2	109	27	105	71	9	6	4	15	35	73	14	44	13	793
Shandong	565	461	281	26	497	7	479	217	716	140	33	119	34	80	100	68	137	221	61	4,241
Henan	245	196	95	10	195	3	320	50	314	96	9	27	8	33	57	100	29	88	12	1,885
Hubei	89	144	124	5	138	3	258	59	290	75	8	25	10	25	160	64	52	117	23	1,669
Hunan	87	130	37	4	147	3	182	68	226	37	5	15	5	24	52	111	25	64	10	1,233
Guangdong	88	357	202	47	523	10	1,108	149	571	300	45	50	67	73	60	115	171	361	118	4,416
Guangxi	64	133	22	2	104	1	108	6	127	46	5	12	4	18	23	53	14	48	8	798
Hainan	7	29	1	0	6	0	33	0	7	10	1	3	1	2	1	1	1	5	1	111
Sichuan	162	197	90	7	194	4	265	3	389	95	14	12	16	31	177	76	61	130	13	1,935
Guizhou	29	50	5	0	17	1	82	0	63	10	1	12	1	4	13	65	19	17	1	391
Yunnan	50	253	9	1	46	3	105	0	122	17	2	8	2	6	30	99	8	20	3	783
Tibet	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	6
Shaanxi	59	51	42	1	55	2	141	17	85	58	2	5	2	8	21	23	14	62	5	653
Gansu	84	26	9	1	16	0	136	56	118	15	2	3	2	6	24	175	9	15	3	698
Qinghai	32	6	3	0	1	0	25	0	14	3	0	0	0	1	12	31	2	3	0	135
Ningxia	19	6	2	0	15	0	47	8	33	3	0	10	0	1	6	22	2	5	0	180
Xinjiang	208	35	36	1	20	0	51	29	26	7	0	4	2	4	14	12	5	5	1	462
National	3,855	3,681	2,726	239	3,793	78	6,801	1,697	7,575	2,093	449	653	345	617	2,337	2,062	1,358	2,810	677	43,848

MI: Mining Industry
FBT: Food, Beverage & Tabacco Processing
TI: Textile Industry
LFRP: Leather, Furs & Related Products
PPP: Papermaking & Paper Products
PI: Printing Industry
PSEP: Production & Supply of Electric Power, Steam & Hot Water
PeP: Petroleum Processing
CI: Chemical Industry
MPI: Medical and Pharmaceutical Industry

CFI: Chemical Fiber Industry
RP: Rubber Products
PIP: Plastic Products
BMON: Building Materials & Other Nonmetal Minerals
SPFM: Smelting & Pressing of Ferrous Metals
SPNM: Smelting & Pressing of Nonferrous Metals
MP: Metal Products
MBEM: Machine Building, Electric Machinery & Electronic Equipment Manufacturing
OI: Other Industries

(unit: 100 million cu.m)

Table 8. Industrial waste gas emissions in regions in 1994.

Region	MI	FBT	TI	LFRP	PPP	PI	PSEP	PeP	CI	MPI	CFI	RP	PIP	BMON	SPFM	SPNM	MP	MBEM	OI	Total
Beijing	34	129	64	5	46	12	2,252	428	335	80	6	36	24	50	3,027	108	383	348	71	7,437
Tianjin	187	109	72	7	59	3	1,838	245	384	94	9	74	24	17	1,882	239	475	272	49	6,037
Hebei	564	162	158	7	138	7	5,922	228	507	177	18	102	35	95	4,271	169	558	220	42	13,382
Shanxi	619	50	28	1	20	2	3,994	96	255	39	6	47	7	23	1,921	232	183	76	7	7,608
Inner Mongolia	164	72	32	2	19	1	2,537	51	73	23	1	7	3	17	1,204	209	86	30	20	4,549
Liaoning	716	208	106	7	122	3	6,942	1,204	731	210	20	172	45	102	7,071	855	780	517	59	19,875
Jilin	185	118	22	1	71	3	3,198	74	503	105	15	34	17	32	691	119	142	252	35	5,618
Heilongjiang	1,465	179	37	2	76	3	4,339	574	144	94	10	78	17	32	711	84	195	144	64	8,251
Shanghai	1	200	257	18	114	11	6,156	302	832	248	135	284	55	54	7,498	691	936	887	140	18,817
Jiangsu	251	426	1,024	36	190	18	8,718	409	1,936	344	182	281	200	209	4,488	1,105	2,044	1,299	273	23,433
Zhejiang	87	268	616	41	187	12	4,332	264	574	188	62	176	166	116	1,084	606	836	557	196	10,367
Anhui	290	276	124	8	98	5	2,891	150	330	83	8	83	39	74	1,547	328	264	200	44	6,842
Fujian	69	195	44	30	155	6	2,942	99	241	55	13	92	67	53	457	98	199	195	112	5,122
Jiangxi	201	109	46	6	56	4	1,824	112	164	111	14	25	13	47	804	363	128	135	35	4,198
Shandong	1,322	719	418	33	370	15	8,022	889	1,121	219	51	506	125	246	2,295	339	1,225	688	168	18,770
Henan	573	305	141	13	145	7	5,360	204	492	150	13	114	28	100	1,318	498	257	273	32	10,024
Hubei	207	224	184	7	102	8	4,314	243	455	118	13	106	36	77	3,679	317	463	365	64	10,984
Hunan	203	203	56	6	109	7	3,054	278	354	57	7	64	17	74	1,209	550	225	199	29	6,701
Guangdong	206	557	300	61	388	25	18,564	612	894	471	69	213	245	225	1,376	572	1,527	1,124	324	27,753
Guangxi	150	207	33	3	78	3	1,810	24	199	72	8	51	15	55	529	265	127	148	22	3,797
Hainan	17	45	1	0	5	0	546	0	10	16	2	14	2	5	26	3	13	17	3	728
Sichuan	378	307	134	9	144	8	4,442	14	609	150	21	52	59	94	4,072	376	547	404	36	11,857
Guizhou	68	78	8	0	12	2	1,366	2	99	16	1	51	5	12	298	321	174	54	4	2,570
Yunnan	117	395	13	1	34	6	1,763	1	191	27	3	34	6	19	688	493	68	62	8	3,929
Tibet	2	1	0	0	0	0	62	0	0	0	0	0	0	1	0	0	0	0	1	67
Shaanxi	137	80	63	1	41	4	2,355	72	134	90	3	21	6	23	481	116	124	194	14	3,959
Gansu	196	41	13	1	12	1	2,282	229	185	23	2	11	6	18	544	869	77	46	7	4,563
Qinghai	74	9	4	0	1	0	425	1	22	4	0	1	1	2	274	154	20	9	1	1,005
Ningxia	45	10	3	0	11	0	779	34	52	4	1	43	2	4	129	111	17	14	1	1,261
Xinjiang	487	55	53	1	15	1	857	119	41	11	1	16	7	13	316	58	47	16	4	2,118
National	9,018	5,740	4,056	308	2,818	182	113,916	6,957	11,865	3,278	695	2,788	1,272	1,888	53,891	10,249	12,122	8,745	1,864	251,652

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Table 9. Industrial waste residue produced in regions in 1994.

(unit: 10,000 ton)

Region	MI	FBT	TI	LFRP	PPP	PI	PSEP	PeP	CI	MPI	CFI	RP	PIP	BMON	SPFM	SPNM	MP	MBEM	OI	Total
Beijing	272	92	19	2	14	2	724	301	180	43	2	4	4	9	232	77	180	79	20	2,255
Tianjin	1,500	77	21	3	18	1	591	172	207	51	3	9	4	3	144	170	223	62	14	3,272
Hebei	4,528	115	47	3	42	1	1,904	160	272	95	6	12	6	18	327	121	262	50	12	7,981
Shanxi	4,969	36	8	0	6	0	1,284	68	137	21	2	5	1	4	147	166	86	17	2	6,961
Inner Mongolia	1,315	51	9	1	6	0	815	36	39	12	0	1	0	3	92	149	40	7	6	2,584
Liaoning	5,748	148	31	3	37	1	2,232	846	393	113	6	20	8	19	542	611	366	117	17	11,257
Jilin	1,482	84	7	1	22	1	1,028	52	271	56	5	4	3	6	53	85	67	57	10	3,292
Heilongjiang	11,754	127	11	1	23	1	1,395	403	77	51	3	9	3	6	55	60	92	32	18	14,122
Shanghai	7	142	76	7	35	2	1,979	212	447	133	41	33	10	10	575	494	439	201	40	4,882
Jiangsu	2,017	303	301	14	58	3	2,803	287	1,041	185	56	32	36	39	344	789	960	294	78	9,640
Zhejiang	699	191	181	16	57	2	1,392	185	308	101	19	20	30	21	83	433	393	126	56	4,314
Anhui	2,327	196	37	3	30	1	929	106	178	45	2	10	7	14	119	234	124	45	13	4,418
Fujian	555	139	13	12	47	1	946	69	130	30	4	11	12	10	35	70	94	44	32	2,253
Jiangxi	1,611	77	14	2	17	1	586	79	88	59	4	3	2	9	62	259	60	31	10	2,975
Shandong	10,611	511	123	13	113	3	2,579	624	603	118	16	58	22	46	176	242	575	156	48	16,635
Henan	4,600	217	41	5	44	1	1,723	144	265	81	4	13	5	18	101	355	121	62	9	7,810
Hubei	1,663	160	54	3	31	1	1,387	171	244	63	4	12	6	14	282	227	218	83	18	4,641
Hunan	1,630	145	16	2	33	1	982	195	190	31	2	7	3	14	93	393	106	45	8	3,897
Guangdong	1,652	396	88	24	118	4	5,967	430	481	253	21	25	44	42	105	409	717	254	93	11,124
Guangxi	1,202	147	10	1	24	1	582	17	107	39	2	6	3	10	41	189	60	34	6	2,478
Hainan	137	32	0	0	1	0	176	0	6	9	1	2	0	1	2	2	6	4	1	380
Sichuan	3,037	218	39	4	44	1	1,428	10	327	80	7	6	11	17	312	268	257	91	10	6,169
Guizhou	543	55	2	0	4	0	439	1	53	9	0	6	1	2	23	229	82	12	1	1,463
Yunnan	940	281	4	0	10	1	567	1	102	14	1	4	1	4	53	352	32	14	2	2,383
Tibet	20	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	41
Shaanxi	1,102	57	18	1	13	1	757	50	72	49	1	2	2	4	37	83	58	44	4	2,353
Gansu	1,577	29	4	0	4	0	733	161	100	13	1	1	1	3	42	620	36	10	2	3,337
Qinghai	596	7	1	0	0	0	137	1	12	2	0	0	0	0	21	110	9	2	0	900
Ningxia	364	7	1	1	3	0	251	24	28	2	0	5	0	1	10	79	8	3	0	787
Xinjiang	3,909	39	16	1	5	0	275	83	22	6	0	2	1	2	24	41	22	4	1	4,454
National	72,369	4,078	1,193	122	858	32	36,619	4,889	6,378	1,762	213	322	229	350	4,130	7,319	5,691	1,978	535	149,068

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In this way, the large environmental loadings from particular regions and branches have been shown. Here, we used the values of environmental loading per industrial product simplified for the nation. It is thought that the value of environmental loading per industrial product in a branch of industry differs by region, so this is a point to consider using regional values in the future.

5. Conclusions

In this paper, we investigated the relationship between regional industrial structure and environmental loading. Our findings in this study are as follows:

(1) The environmental loading in the provinces of Jiangsu, Shandong and Guangdong is large, and has increased year by year. The provinces of Liaoning and Sichuan have also a large environmental loading; nevertheless, the increase in environmental loading is not large.

(2) The branches of "smelting and pressing of ferrous metals", "chemical industry" and "production and supply of electric power, steam and hot water" have large values of industrial waste water and gas. "Machine building, electric machinery and electronic equipment manufacturing" is a branch which has a smaller environmental loading in spite of large industrial products.

(3) The large environmental loadings from particular regions and branches have been shown; for waste water, "the chemical industry" in the provinces of Jiangsu and Shandong, and "the production and supply of electric power, steam and hot water industry" in Guangdong; for waste gas, "the production and supply of electric power, steam and hot water industry" in the provinces of Guangdong, Jiangsu and Shandong, and "the smelting and pressing of ferrous metals industry" in the municipality of Shanghai and the province of Liaoning; and for waste residue, "the mining industry" in the provinces of Heilongjiang and Shandong, and "the production and supply of electric power, steam and hot water industry" in Guangdong.

Acknowledgment

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