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Urbanization and Environmental Management in Shenzhen City

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1. The Backgrounds of Shenzhen City

Shenzhen City is located on the south coast of Guangdong Province, bordering the Daya Bay in the east and harboring the mouth of the Pearl River in the west. Separated by the Shenzhen River in the south, it is contiguous to the Xinjie District of Hong Kong, and borders on the cities of Dongguan and Huizhou in the north (see Fig.1). The land area of Shenzhen City is 1949 Km^2. The latitudinal and longitudinal position of Shenzhen City is 22° 26'59''~22° 51'49''N and 113° 45'44'' ~ 114° 37'21''E. In terms of administrative areas, the city is divided into two main parts, namely the Special Economic Zone and the districts of Bao'an and Longgang. The former lies in the southern part of Shenzhen City, including the four districts of Futian, Luohu, Nanshan and Yantian. With an EW length of 49 Km and SN width of 7 Km, the Special Economic Zone comprises a total area of 391.75Km^2.

Table 1 Weather conditions in Shenzhen

Factor \ Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Average temperature(℃)	14.3	15.0	18.2	22.2	25.7	27.4	28.4	28.0	26.8	24.2	20.0	16.0	22.2
Sunlight hours(h)	160.7	106.9	110.0	123.7	171.1	178.9	238.0	210.8	193.4	209.1	192.0	191.9	2086.4
Earth surface temperature(℃)	16.5	17.5	20.8	24.8	28.7	30.1	31.7	30.9	29.7	27.2	22.4	18.1	24.9
Precipitation (mm)	26.9	43.3	68.6	158.7	235.9	281.5	314.0	345.4	236.8	104.1	36.2	25.2	1876.6
Evaporation (mm)	109.1	90.2	112.1	129.5	158.4	160.5	187.1	170.4	160.7	166.3	140.1	123.1	1707.5
Relative humidity(%)	72	78	80	82	83	84	82	84	81	75	71	69	78
Days of Rainfall(day)	7.0	9.1	11.0	11.6	15.6	19.8	18.0	18.8	15.5	7.9	5.3	5.1	144
Frequency of typhoon					0.2	0.7	1.6	2.0	1.9	0.6	0.3	0.03	7.3
Average speed of wind(m/s)	2.8	2.9	2.8	2.7	2.4	2.1	2.1	1.9	2.3	2.7	2.9	2.8	2.5
Dominant wind	NNE	NEE SEE	SEE	SEE	SEE	SEE	SW	E	NE	NEE	NNE	NNE	E

Shenzhen City has a subtropical monsoon climate (Table 1). Shenzhen River is the main river. The soil of horizontal zonality developed in Shenzhen City is laetrile. The typical zonal vegetation of Shenzhen City is the tropical evergreen monsoon forest and the subtropical monsoon evergreen broad-leaved forest.

On April 1979, the State Council ratified Bao'an County and named it Shenzhen City, a joint decision led by Huiyang Prefeture and Guangdong Province. In the same year, the Central Committee of CPC decided to experimentally make Shenzhen as a special economic zone in July and placed the municipality of Shenzhen City directly under the Central Government. In August 1980, the Standing Committee of the National People's Congress passed and issued "Regulations for the Special Economic Zone of Guangdong Province," establishing the special economic zone across an area of 327.5 km^2 in Shenzhen City. The region outside of the special economic zone was called Bao'an County again in August, 1981. In the 1990s, the County was divided into two districts, Bao'an and Longgang, and declared part of Shenzhen City.

Upon its establishment, Shenzhen Special Economic Zone pursues a "market-oriented economy." It was the first city in China to introduce an economic system reform and management reform. As the first window for China to the outside world, Shenzhen has attracted huge foreign investments, foreign-owned enterprises and joint ventures, introduced into China advanced technologies, products, recent information and managerial methods, and fostered a great number of high-quality managers.

The preferential policies that these special economic zones provide include two parts: Preferential policies for enterprises endow the full autonomy for enterprises to run their business. These enterprises are granted tax privileges. All exports made from imported materials are exempt from customs duties, product tax and VAT. Preferential policies for the administration of special economic zones give the local government wider judicial power in management with respect to project authorization, design of economic plans, trade control and personnel management. These zones are also given a freer hand to collect funds.

Equipped with these privileges, the special economic zones were the first in China to undertake fundamental system reforms in pricing, employment, rewarding, personnel and financing. They also conducted reforms in state-owned enterprises, housing, unemployment insurance, pension and health insurance. The first stock market and foreign exchange market in China emerged in the special economic zones.

The successes of preferential policies and structural reforms in the special zones enabled the Shenzhen special economic zone to achieve higher economic growth rates. In the 18 years from 1980 to 1998, Shenzhen's GDP averaged an annual increase of 32.3%, GDP per capita 16.0%, gross industrial output value 49.5%, investment in fixed social assets 42.2%, local revenue 43.5%, and exports 44.2% respectively.

All the above figures indicate that Shenzhen has become a highly developed international metropolis.

By 1997, the volume of waste water increased from 136.85 million tons in 1990 to 330.32 million tons, industrial waste water from 15.52 million tons to 22.17 million tons, disposed industrial waste water from 5.84 million tons to 29 million tons, industrial smokes from 2.15 billion cubic meters to 45.82 billion, disposed industrial smokes from 1.15 billion to 30.27 billion, sulfur dioxide from 1,166 tons to 21410 tons, solid industrial refuse from 21,914 tons to 343.200 tons (the disposing capacities of which increased from 2,567 tons to 51,700 tons) and industrial dust decreased from 136 tons to 58 tons. In addition, the area of land erosion also increased notably, up to 96.7km^2.

2. The DPSER Model of Shenzhen

2.1 Developmental Stages in the growth of economy and environment

Shenzhen was a direct product of the open-door reform policy of the Central Government of China, so its development is closely linked with policy input. We divide the city development into four stages.

- **The first stage: The establishment of Shenzhen—from Bao'an County to Shenzhen City (before 1979)**

In April of 1979, the State Council approved the application for the conversion of Bao'an County into Shenzhen. The city was then under the leadership of Guangdong Province. In July of the same year, the Central Government decided to experiment with special economic zones, and consequently changed Shenzhen into a municipality directly under the Central Government. At the time of its establishment in 1979, Shenzhen's population had increased from 268,300 in 1949 to 314,100. By the end of 1979, the city recorded a GDP of 196.38 million yuan, of which the primary industry recorded 72.73 million yuan, the secondary industry 40.17 million yuan, and the tertiary industry 83.48 million yuan.

Its GDP per capita was only 606 yuan. The overall social investment accounted for 59.38 million, of which 49.88 million yuan was invested in construction of infrastructure. The local revenue was recorded at 17.21 million yuan. At the time, the cultivatable land covered 354.7Km^2, with a total agricultural output of 130 million yuan. The industrial output value was recorded at 71.28 million yuan. The farming on the upland caused severe land erosion often found in semi-tropical ecological systems.

- **The second stage: the initial stage from the establishment to the "June 4th" incident (1980-1989)**

In August 1980, the Standing Committee of the National People's Congress enacted "Regulations on Special Economic Zones in Guangdong Province," allocating an area of 327.5 square kilometers in Shenzhen for the Shenzhen Special Economic Zone. The original area outside the zone was restored as Bao'an County in August of 1981. This period witnessed a rapid growth in the construction of infrastructure. Through a decade's effort, the special zone evolved into a successful region. The completed construction area increased 21 times from 2.9 square kilometers in 1979 to 60.12 square kilometers in 1989, when the population of the city reached 1.96 million. The population of the special zone increased from 94,100 in 1980 to 1.02 million. In 1989, the GDP of the zone was recorded at 11.56 billion yuan, of which the primary industry constituted 690 million, the secondary industry 5.05 billion, and the tertiary industry 5.83 billion yuan. The GDP per capita stood at 6,710 yuan, overall social investment 5 billion (including 4.35 billion in infrastructure investment), local revenue 2.29 billion, cultivated land 108.3 Km^2, agricultural output 1.08 billion yuan, and industrial output 14.78 billion yuan. Because of the quick expansion of coastal areas, the structure of land use changed dramatically. According to 1988 TM estimation, the area used by town increased from 0.38% in 1980 to 7.74% in 1988 (using MSS data estimation).

Several environmental problems emerged as a key factor in urban development in Shenzhen. By 1989, the city discharged 120.74 million tons of waste water (11.93 million tons of industrial waste water), 3.84 billion cubic meters of industrial smokes and 979 tons of sulfur dioxide, while it had a handling capacity of 4.01 million tons for disposing industrial waste water and 1.99 billion cubic meters for the disposal of industrial smokes. These figures indicated that coordination between economic development and environmental protection had become an urgent necessity.

- **The third stage: industrial transformation re-orientation—from resource-labor-intensive to capital-technique-intensive (1990-1997)**

In 1989, China experienced political turmoil with the increasing criticism on the open-door reform policy. This gave rise to opposing views from local to central government on the experiment of special economic zones. The changing situation at both home and abroad forced the experimental zones to reconsider their policies on the direction of their development. After the "June 4th" incident, China began an economic "renovation and consolidation." This new policy was bound to affect the development of the Shenzhen special zone.

From 1989 to 1992, the opening-up and reform process in Shenzhen slowed down considerably. After Deng's speech in 1992, the city embraced its second peak of construction. On August 11, 1992, the State Council cancelled Bao'an County and established Bao'an district and Longgang district within Zhenzhen municipality. Up until 1997, when China recovered its sovereignty over Hong Kong, the Shenzhen special zone had applied the Central Government's policy of "economic soft landing." During this period, the municipality experienced a period of industry-reorientation from a resource-labor-intensive perspective in the previous decade to that of a capital-technique-intensive one. By 1997, the city area of the special zone had reached 124 square kilometers, over twice of the area in 1989. The population of the city increased to 3.79 million, including 1.75 million in the special zone. Its GDP increased to 113 billion yuan (primary industry 1.58 billion, secondary 55.66 billion and tertiary 55.76 billion). The GDP per capita reached 30,689 yuan. The overall social investment totaled 39.31 billion yuan, including 20.16 billion yuan in infrastructure construction—a sharp decrease in proportion. The local revenue amounted to 14.48 billion yuan, cultivated land 42.4 Km^2, agricultural output 2.71 billion yuan, and industrial output 166.61 billion yuan.

As the city expanded, the level of urbanization also increased: the land used by the city reached 20.41% (by TM estimation, 1994). As urban environmental problems worsened in Shenzhen, renovation measures were also consolidated, and annual financial input in this respect increased gradually. By 1997, discharge of waste water increased to 300.32 million tons, including 22.17 million tons of industrial waste water. The disposing capacity of industrial waste water increased to 29 million tons. The emission of industrial smokes reached 30.56 billion cubic meters, the disposing capacity of which was 30.27 billion tons (an increase in percentage from 50% in 1989 to 96%), sulfur dioxide 18,916 tons, industrial dust 63 tons (the amount of retrieved dust 2 tons), and industrial solid refuse 340,300 tons (disposing capacity 52,000 tons).

- **The fourth stage: industrial complementary development with Hong Kong—a shift from resource-labor-intensive to capital-technique-intensive (1998-2010)**

As Hong Kong returned to the mainland China, the establishment of the Hong Kong special administrative region provided Shenzhen with a good development opportunity as well as new challenges. Approaching toward next century, all the citizens in Shenzhen pay great attention on the direction of urban development in Shenzhen's special zone. The task facing the newly elected local government was how to push the city into a third peak of rapid development. Since 1998, Shenzhen had put more efforts into readjustment with special emphasis on the development of high-tech industry, such as information technology, biological technology, environmental protection and health industry. At the same time, it quickened steps in renovation and construction of infrastructures, and increased input into city greening and environmental protection. The transportation network of the city had been expanded, and the tertiary industry led by tourism and financial services were restructured to enhance both quality and quantity. The reorientation of industries makes it possible for Shenzhen to coordinate its growth with Hong kong in the direction of a final combination and unification.

Such a growth pattern poses higher demands on the building of city environment. A pattern of coordinated development between economic growth and environment began to take shape. Based on the results of our case study, we labeled the first stage of the city and environmental development pattern as the stage of Eco-Awareness, the second stage as Eco-Industry, the third as Eco-city. The present stage is a transition stage from Eco-City (an honor endowed by the state to the municipality in 1997) to Eco-Society. We anticipate that the present stage will last through 2010, when it will transfer into the Eco-Meaning stage, the time when a perfect coordination between city development and eco-environment will be realized through a sustainable growth.

Table 2 DPSER of Shenzhen

Stage	Before 1979	1980 - 1989	1990 - 1997	1998 - 2010
Representative events	• Evolution from Bao'an County to Shenzhen municipality	• The establishment of Shenzhen special zone; the political turmoil in late spring and early summer of 1989	• Deng Xiaoping's speech delivered in 1992 on his southern tour; the return of Hong kong (the establishment of Hong kong special administrative region in 1997	• Hong kong special administrative region meets the southeast Asian financial crises; unprecedented flood in China in 1998
(D) Driving forces behind environmental problems	• Local agricultural policies of Guangdong province • Semi-tropical climate in southeast coast; coastal upland	• The opening-up and reform policy in application in Shenzhen • Foreign investment enterprises development • High growth of economy • Rapid urbanization	• Criticism against the reform policy • Preferential policies and high growth of economy • Real estate grows quickly • Foreign investment enterprises development	• Complementary industrial system in Shenzhen • Integration of industries in Shenzhen •
(P) Environment pressure	• Demand of food from city and country residents	• Big increase of city population • Enormous increase in water and energy consumption • Big increase in over-all population • Infrastructure construction quickens • Development of resource-labor-intensive industries	• Expansion of completed city • Some processing industries move out of the special zone • Infrastructure construction quickens • Living standards raised • Fast development of the secondary and third industries • Structural readjustment accelerates	• Protection of water and land resources degenerate • Industrial competition increases between Shenzhen and Hongkong • Fierce competition in world market
(S) Status of environment	• Degeneration of land (erosion and red soil)	• Environmental pollution increases • Destruction of eco-system • Decrease of green coverage • Land coverage changes notably	• Air pollution becomes worse • Seashore water pollution worsens • Land erosion increases • Naked land expands	• City environment quality to be improved • Environment emergencies become more difficult to handle
(E) Effect on ecosystem and social-economic system	• Damage of land erosion on agricultural output	• Eco-serving function of plantation decreases • Levels of eco-environment safety decreases • Frequent flooding • Flooding affects city	• Occurences of environment incidents • Health environment of city residents in danger • Warming effect of the city changes the capacity of environment • Effects on the quality of air and water in the city	• City sight-seeing develops fast • Investment of foreign enterprises • Shortage of "environmental resources"
(R) Response to be taken	• Renovate land erosion to increase agricultural productivity	• Accelerate planning of area and city land utilization • Quicken environmental protection construction in city and country	• Make and apply the eighth and ninth five-year plans on environmental protection • Speed up renovation of city traffic	• Increase of investment in environmental protection infrastructure • Unifying environment standards of Shenzhen and Hong

		• Propose regulations on environmental protection • Strengthen the administration of environmental protection	• Shorten the time in building key environment projects • Enlarge the area of city greening • Strengthen the execution of environmental protection regulations • Improve environment information management	kong is called • Establish a unified system to protect water and air in two cities • Enact a unified environmental protection plan for Pearl River delta

3. Driving Forces of Urban Development and Environmental Change in Shenzhen

3.1 Population Change and Urbanization

The "registered permanent population" of Shenzhen City was 312600 persons in 1979 and 1,146,000 in 1997. The "temporary population" of Shenzhen City was 1500 in 1949 and 2,803,600 in 1998. During this period, it added 280,210 persons, an average of 147,500 persons each year or 3.36 times the resident population's. As shown in Table 3, the level of urbanization in Shenzhen had exceeded 70% by 1992 and reached 75.4 % in 1995.

Table 3 Population change and urbanization level of Shenzhen City

Year	Resident population (10,000)	Registered permanent population (10,000)	Temporary population (10,000)	Agriculture population of registered permanent population (10,000)	Non-agriculture population of registered permanent population (10,000)	Urbanization level of registered permanent population (%)
1979	31.41	31.26	0.15			
1980	33.29	32.09	1.20			
1981	36.69	33.39	3.30			
1982	44.95	35.45	9.50			
1983	59.52	40.52	19.00			
1984	74.13	43.53	30.61			
1985	88.15	47.86	40.29			
1986	93.56	51.45	42.11	25.00	26.45	51.0
1987	115.44	55.60	59.84	24.99	30.61	55.1
1988	153.14	60.14	93.00	25.17	34.96	58.1
1989	191.60	64.82	126.78	25.48	39.34	60.7
1990	201.94	68.65	133.29	25.65	43.00	62.6
1991	238.53	7.22	165.31	26.23	46.99	64.2
1992	260.90	8.22	180.68	22.83	57.39	71.5
1993	294.99	87.69	207.30	23.61	64.08	73.1
1994	335.51	93.97	214.54	24.41	69.56	74.0
1995	345.12	99.16	245.96	24.39	74.77	75.4
1996	358.48	103.38	255.10	24.47	78.91	76.3
1997	379.64	109.46	270.18	24.66	84.80	77.5
1998	394.96	114.60	280.36	24.69	89.91	78.5

It is remarkable that the level of urbanization can increase 27.5% during the thirteen years from 1986 to 1998. The fact that the temporary population reached 70.98% of resident population in the course of urbanization suggests that environmental problems result from damage and output not only by the registered permanent population but also by the temporary population in their productive activities.

3.2 Economic Development in Shenzhen

3.2.1 Changes in total economic volume

The economic development of Shenzhen truly reflects the success of the opening-up and reform policy in China. From 1980 to 1998,the city saw an average annual increase of 3% in population, 32.2% in GDP, 16.0% in GDP per capita, 42.2% in fixed assets investment, 50.0% in bank deposit, 39.7% in employee salary, 6.2% in agricultural output value, 49.5% in industrial output, 35.2% in retail volume of social commodities, and 46.2% in imports and exports.

The economic development in Shenzhen can be divided into the following four periods: (1)before the special zone came into being in 1979, (2) 1980-1989 when the zone was established, (3) 1990-1997 when the zone underwent industrial transformation, and (4) incorporation stage between Shenzhen and Hong Kong after 1998.

Table 4 Index of Shenzhen City in China's Economy

	Total					
	1979	1980	1985	1990	1995	1998
Gross Domestic Product (100 million RMB)	1.96	2.70	39.02	171.67	795.70	1289.01
Total fixed assets investment of the whole society (10 thousands RMB)	0.59	1.29	33.32	57.92	275.82	480.39
Capital construction	0.50	1.25	27.61	42.71	140.12	239.57
Money deposit (100 million RMB)	1.01	2.03	30.26	194.69	1202.93	2238.37
Total wages of all staffs and workers (100 million RMB)	0.30	0.45	5.19	22.74	107.61	167.48
Gross value of agricultural output (100 million RMB)	1.31	1.69	4.58	11.92	23.27	29.81
Gross value of industrial output (100 million RMB)	0.71	1.06	24.67	220.22	1226.49	1943.52
Total turnover from retail trade of social consumer goods (100 million RMB)	1.13	1.96	26.56	66.76	259.33	423.05
Volume of import and export trade (10 thousands US dollars)	0.17	0.18	5.63	29.96	205.27	4527.42

3.2.2 The changes of the industrial structure

At the early stage of Shenzhen's development, there was no ready-made model for the industrial development to follow. According to the characteristic of Asian economic situation at the time, in such places like Hong Kong, Taiwan, Singapore, South Karea, Tailand there was not much market for manufactural industry after ten-years' rapid increase in its production; so the move-out of the process industries for export was inevitable. Thus, Shenzhen decided to take the chance to develop an industrial system with the processing industries for export as its feature. From 1979 to the end of 1985, Shenzhen had changed its agriculture based single-mode economy, and built its industrial system mainly for exportation with electronic industry as its main body. The proportion of the three major industries changed from 37.0: 20.5: 42.5 in 1979 to 1.3: 50.0: 48.7 in 1998. It has been changed from an agricultural production to an industrial production. In fact, after 1993, the proportion of the secondary industry was obviously higher than that of the tertiary industry. Then, the speed of the development of the secondary industry slowed down whereas that of the tertiary industry constantly increased.

3.2.3 Introduction of foreign investment and economic growth

From 1980 to 1998, foreign investment constituted 58.98% of the total social investment in fixed assets (1 US dollar = 8.2 yuan in 1998). Of realized foreign investment in this period, 65.76% was in industry, 10.94% in real assets and social services, 3.06% in transportation and communication, and 20.24% in other industries.

Table 5 Foreign investment introduced and fixed assets investment in Shenzhen

Item / Year	Total social investment in fixed assets (1000 yuan)	Amount of actual realization of foreign investment (1000 US dollars)	Realized foreign investment in industry (1000 US dollars)	In transportation and communication (1000 yuan)	In real estate and social services (1000 US dollars)
1979	5938	1537	645	31	553
1980	13801	3264	1371	65	1175
1981	29684	11282	4738	226	4061
1982	73750	7379	3099	148	2656
1983	108320	14394	6013	273	5124
1984	194572	23013	8235	881	4412
1985	333235	32925	6549	1457	7976
1986	248551	48933	31874	416	2965
1987	285193	40449	25216	432	454
1988	436191	44429	28645	917	4652
1989	499919	45809	27406	1071	4744
1990	579222	51857	32306	440	5576
1991	793620	57988	34869	894	10835
1992	1410128	71539	44056	300	9503
1993	1950507	143217	74851	18514	31664
1994	2309567	172959	113192	18900	14220
1995	2758243	173545	121125	17195	15982
1996	3275270	242242	193141	6944	16970
1997	3930657	287168	222822	26095	14372
1998	4803901	255222	156925	35333	31208
Total	24040269	1729151	1137078	52991	189102

In other words, the investment was concentrated in the secondary and tertiary industries. This demonstrates that the rapid industrial and tertiary industry growth had close links with the realization of foreign investment, which acted as a catalyst. It is the secondary and tertiary industries that pushed the re-orientation of industrial structure, determined regional environmental quality and forced the changes in the environment.

3.3 Development of Real Estate in Shenzhen Special Zone

The rapid economic growth in Shenzhen quickened the pace of urbanization. This is not only shown in the continual increase of the proportion of the non-agricultural population, but also in big changes in the structure of land utilization in the city. Due to the development in real estate, the percentages of land used by the three industries changed greatly. These changes have a direct bearing on the capacity of the environment and its safety level, indicating that industries are the sources of pollution. The built-up area rose from 3.8 Km^2 in 1980 to 129.0 Km^2 in 1998.

3.4 Land Use/Cover Change in Shenzhen

We have analyzed the land use in Shenzhen in three phases, according to the remote sensing data collected in 1980, 1988 and 1994. The data in 1980 stand for the pre-special economic zone phase, the data in 1988 stand for the construction period of the special economic zone, and the data in 1994 stand for the industry transferring period of the special economic zone.

Table 6 Comparison of the remote sensing measurement of land use/cover change in Shenzhen

Year	Type	High Density Urban Land Use	Middle Density Urban Land Use	Cropland	Orchard	Woodland	Irrigated Grassland	Wetland	Water	Bare Land	Total
1980	Area(km^2)	0.00	6.85	49.34	0.00	397.92	391.05	15.81	455.58	18.92	1785.50
	Percentage	0.00	0.38	27.97	0.00	22.2	21.90	0.89	25.52	1.06	100.00
1988	Area(km^2)	2.08	136.12	358.43	355.21	373.65	0.00	69.56	456.73	33.67	1785.50
	Percentage	0.12	7.62	20.07	19.89	20.3	0.00	3.90	25.58	1.89	100.00
1994	Area(km^2)	4.36	360.14	134.22	346.54	369.0	0.00	18.81	497.40	53.99	1785.5
	Percentage	0.24	20.17	7.52	19.41	20.72	0.00	1.05	27.86	3.02	100.00

4. State of the Environment of the City

4.1Present situation of Shenzhen City environmental pollution (1998)

The major problems are air pollution, water pollution, noisy and soil erosion. The average density of all suspended solids per day of year is 92 micrograms per cubic meter, descending 3.2% when compared to 1997. The average density of sulphide dioxide per day of year is 9 micrograms per cubic meter, ascending 12.5% when compared to 1997. Average density of nitrogen and oxide per day of year is 62 microgram per cubic meter, ascending 14.8% when compared to 1997. Average value of dust by year is 5.03 tons per kilometer and per month, descending 13.0% when compared to 1997. Average pH value of rainfall by year is 4.64, descending 0.27 when compared to 1997. Frequency of acid rain to total rainfall is 59.2%, ascending 13% when compared to 1997. Amount of acid rain to total rainfall is 68.6%, ascending 13% when compared to 1997.

The quality of main drinking water of Shenzhen City is better. Its ratio to the standard is 97.2%, ascending 0.4% compared to 1996. But rivers are polluted severely, in which the main pollutants are total nitrogen, ammonia nitrogen, total phosphorus and oil. Contents of inorganic nitrogen, inorganic phosphorus in eastern coastal waters exhibit a rising trend, while those of western coastal waters have little decrease. Among noise sources in the city, the living noise source makes up 47.7% and traffic source 33.6%. The average value of regional environmental noise of Shenzhen City is 57.2 decibels, and its ratio to the standard is 80.7%. The average value of city artery communication is 69.8 decibel and its ratio to the standard is 53.2%.. The forest cover ratio of the city is 47.4%. The green cover ratio of construction area of the Special Economic Zone is 44%. Natural protected area of the city is $125.1km^2$ and its cover ratio is 6.2%.The area of soil erosion is 96.7 km^2, accounting to 4.8%.

4.2Pollution Source and Industries

To uncover the city's state of environmental pollution sources, a survey of pollution sources was conducted by the Shenzhen Environmental Protection Bureau. The criterion year of the survey was 1996, and 22788 enterprises were investigated, of which 9561 enterprises were industry and 13227 enterprises belonged to the catering trade, recreation, service, hospital, communication and transportation, etc. (hereafter referred to as "the tertiary industry"). The survey collected more than 1.6 million data in all, according to which the industrial pollutants and their distribution state were determined.

In 1996, the survey collected 9561 pieces of industrial reports and 13227 pieces of tertiary reports. Except the repetitions and the report forms from communication and transportation and car washing, etc., the survey included 9169 industrial enterprises and 10910 enterprises from the tertiary industry. Table 7 shows the basic data of the survey. Seen from the number of enterprises, the coverage percentage amounts to 94.8%. The survey of environmental pollution sources included 42 industries of enterprises and 8 businesses of cartering trade, tourism, beauty treatment, medical care and transportation.

Table 7 Sources of pollution in Shenzhen

	Unit	Total pollution sources	Industry pollution sources	Tertiary industry pollution sources
Number of enterprises		20079	9169	10910
Output value (Operating income)	100 million yuan	1863.16	1767.42	95.74
Discharge payment	10000 yuan	5445.10	2366.82	3078.28
Total investment in EP treatment facilities	100 million yuan	11.97	10.94	1.03
Operating cost of EP treatment facilities	100 million yuan	1.66	1.47	0.19
Total amount of industrial (enterpriese) water use	10000 t	19563.20	16323.23	3239.97
Sewage discharge	10000 t	7941.33	5110.80	2830.53
Sewage treatment	10000 t	4843.05	4084.59	758.46
Gas consumption	ton	28134.47	13990.05	14144.42
Coal consumption	10000 t	130.17	130.05	0.12
Fuel consumption	10000 t	196.28	193.00	3.28
Electricity consumption	100 million KWh	37.43	31.83	5.62
Total exhaust emission	100 million m^3	541.43	496.08	7.92
Combustion exhaust	100 million m^3	447.14	439.22	7.92
Industrial exhaust	100 million m^3	56.86	56.86	—
Solid waste production	10000 t	51.69	40.88	10.81
Solid waste discharge	10000 t	4.87	4.87	0.00
Comprehensive utilization of solid wastes	ton	30.58	30.58	0.00

Table 8 Industrial distribution of enterprises in Shenzhen

Industry	Number of enterprises		Number of workers		Gross value of industrial output		Fixed assets		Amount of water use	
		% of the city's industry	10000 persons	% of the city's industry	100 million yuan	% of the city's industry	100 million yuan	% of the city's industry	10000 t	% of the city's industry
Plastic product's	1200	13.1	15.1	12.4	125.4	7.1	64.7	5.2	1810.0	11.1
Metal products	1024	11.2	9.85	8.0	86.3	4.9	170.4	13.6	706.9	4.3
Electronic and communication equipment	873	9.5	19.7	16.1	587.0	33.2	116.2	9.3	2066.3	12.7
Clothing and other fibre products	790	8.6	12.1	9.9	76.4	4.3	46.7	3.7	504.6	3.1
Electric machine and equipment	554	6.0	11.4	9.2	143.0	8.1	48.5	3.9	580.9	3.6
Education and sports goods	449	4.9	8.8	7.2	49.3	2.8	31.1	2.5	430.4	2.6
Paper-making and paper products	448	4.9	3.0	2.4	97.9	5.5	34.2	2.7	511.0	3.1

Leather, fur, down and other products	428	4.7	7.4	6.1	42.7	2.4	16.8	1.3	340.7	2.1
Chemicals	395	4.3	3.1	2.5	39.5	2.2	18.5	1.5	193.5	1.2
Production and supply of electricity, steam	19	0.2	0.5	0.4	100.7	5.7	422.8	34.0	4051.8	24.8
Total (% of the city's)	6180	67.4%	90.95	74.2%	1348.2	76.2%	969.9	77.7%	11196.1	68.6%

Table 9 Tertiary industry distribution in Shenzhen

Name of enterprises	Number of enterprises		Number of workers		Fixed assets		Income		Amount of water use	
		% of the tertiary	10000 persons	% of the tertiary	100 mill. yuan	% of the tertiary	100 mill yuan	% of the tertiary	10000 t	% of the tertiary
Food and drinking service	6719	61.6	8.04	43.3	21.19	18.0	35.39	37.0	1356.62	41.9
Beauty treatment	3652	33.5	1.67	9.0	1.23	1.0	3.89	4.0	275.06	8.5
Hotel	293	2.7	3.02	16.3	62.30	52.8	24.77	25.9	1054.92	32.6
Recreation service	122	1.1	0.73	3.9	18.48	15.7	6.57	6.9	210.93	6.5
Medicine and health	58	0.5	1.36	7.3	11.84	10.0	12.07	12.6	312.07	9.6
Communication and transportation	57	0.5	3.57	19.2	1.66	1.4	9.07	9.5	7.33	0.2
Total (% of the city's)	10901	99.9%	18.39	99.0%	116.7	98.9%	91.76	95.9%	1356.62	99.3%

Note: The data of city communication and transportation are omitted.

4.3 Energy consumption and exhaust emission

The consumption and distribution of primary energy play an important role in the environment, especially the atmospheric environment of cities with agglomerated industries. Oil, electricity, coal and gas are the main components of the city's energy. Among them the exhaust gases produced in the process of burning coal, oil and gas are the major factor to cause the atmospheric environment pollution. Table 10 shows the consumption of oil, electricity, coal, gas and their respective standard coals.

The energy consumption per 10,000 RMB industrial output value is 0.22 t/10000 RMB in the city, which is 23.6 times lower than the national average, of 5.02 t/10000 RMB reported in the 1985 national industrial pollution source survey. It is the result of high level industrial techniques and management, production of high-tech products and advanced manufacturing. The generation and supply of electricity, steam and hot water is the industry with the biggest energy consumption, occupying 47.9% of the total. The consumption of coal and oil accounts for 96.2% and 45.9% of the total, respectively.

Table 10 Energy consumption in Shenzhen

Energy		The city			Industry			Tertiary Industry		
		Consumption	Standard coal (10000t)	% of the city	Consumption	Standard coal (10000t)	% of the city	Consumption	Standard coal (10000t)	% of the city
Fuel (10000 t)	Total	196.28	306.81	55.5	193.00	301.69	57.5	3.28	5.08	17.5
	Heavy oil	10.73	15.31	2.8	10.69	15.28	2.9	0.04	0.05	0.2
	Light oil	185.55	291.50	52.7	182.31	286.41	54.6	3.24	5.03	17.3
Electricity (100 mill KWh)		37.44	151.28	27.3	31.83	128.58	24.5	5.62	22.70	78.1
Coal (10000 t)		130.17	92.94	16.8	130.05	92.86	17.7	0.12	0.09	0.3
Gas (10000 t)		2.81	2.41	0.4	1.40	1.20	0.2	1.41	1.21	4.2
Total		-	553.44	100	-	524.33	100	-	29.08	100

Note: The coefficients of standard coal: 0.714kg standard coal/kg coal; 1.429 kg standard coal/kg heavy oil; 1.571 kg standard coal/kg light oil; 0.857 kg standard coal/kg gas.1m^3 gas weighs 2 kg. 4.04 t standard coal/10000 KWh.

The main industries of coal consumption are the generation and supply of electricity, steam and hot water as well as non-metal mineral products, making up 96.2% and 1.7% of the total coal consumption respectively. Food processing and plastic products are the main consumption of heavy oil, occupying 52.0% and 21.0% of the total respectively. Of 1996 total exhaust emission of the city, the industrial exhaust accounted for 99.1% and the tertiary exhaust only 0.9%. Exhaust gases can emit several dozens of pollutants. This survey only includes the main toxic materials of SO_2, smog, industrial dust and fluoride (Table 11).

Table 11 Exhaust pollution emission in Shenzhen

Pollutants in exhaust	The city		Industry		Tertiary industry	
	Emission (t)	Of the total	Emission (t)	Of industry's	Emission (t)	Of Tertiary's
Total amount of pollutants	32787.56	100.0	32439.69	100.0	347.87	100.0
SO_2	26707.85	81.5	26430.29	81.5	277.56	79.8
Smog	5586.46	17.0	5516.15	17.0	70.31	20.2
Industry dust	331.50	1.0	331.50	1.0	-	-
Fluoride	161.75	0.5	161.75	0.5	-	-

In terms of industries, the exhaust emission and pollutant discharge by the production and supply of electricity, steam and hot water rank first, occupying 51.4% and 58.8%, and far exceed the other industries. The other three enterprises emitting great deal of exhaust are the non-metal mineral products, plastic products and electronic and communication equipment.

4.4 State and assessment of enterprise water consumption and waste water discharge

The state of enterprise water consumption is shown in Table 12. Few enterprises use surface water directly because it has been contaminated to some extent, and the present water consumption situation is quite different from that in 1989.

Table 12 State of water use in enterprises in Shenzhen

Item		Whole city	Secondary industry	Tertiary industry
Total water consumption of enterprise		19563.20	16323.23	3239.97
Fresh water	Water quantity (10^4 t)	12758.31	9547.26	3211.05
	Proportion to total water consumption(%)	65.2	58.5	99.1
Water reused	Water quantity(10^4 t)	6804.89	6775.97	28.92
	Water reuse proportion(%)	34.8	41.5	0.9

The average water consumption per output value of the tertiary industry is 33.84 t/(10000 yuan), but it is 5.40 t/(10000 yuan) in the secondary industry and is 28.44 t/(10000 yuan) more than that of the tertiary industry.

The three largest water-consuming industries are the industry of electricity, steam and hot water, the industry of electronic and communication, and the industry of nonmetal mineral production, which together occupy 48.5% of the total water consumption in Shenzhen city. The largest water-recycling industry is electricity, steam and hot water, which occupy 44.4% of water reused, and its main water circulation is for cooling . The electronic and communication products occupy 10.4% of water circulated. Food and hotel consumed 74.5% of water. Hairdresser and cosmetics stands were forth, but their average output per water consumption ranks first. The secondary and tertiary industries discharge 64.4% and 35.6% of waste water respectively. Waste water treatment rate is 61.0% for the city, 79.9% for the secondary industry and 26.8% for the tertiary industry. The average waste water discharge per output is 2.89 t/(10^4 yuan). And three areas in the special zone are lower than this level, but the quantity from the special zone is higher than the average value.

Waste water discharge was mainly in the 7 sectors shown in Table13, which discharged 69.1% of total waste water. Textile industry discharged most waste water, about 22.10 t/(10^4 yuan) which is 7.6 times the average level. Printing and dyeing enterprises consumed a large quantity of water and their waste water rate was the largest of all. From the view of resource utilization and pollution, the increase in textile industry of Shenzhen City should be considered carefully.

Waste water discharge and treatment of the tertairy industry is mainly concentrated in food and hotel sectors(Table 14), and the waste water rate is high. The total waste water treatment in the hairdressing and cosmetic sector is the least, only 1.1% of the total, and waste water treatment rate is also lowest, only 3.5%.

Table 13 Waste water discharge in different sectors of the secondary industry

Sectors	Waste water discharge		Percentage of waste water conversion (%)	Waste water treatment		Waste water discharge ($t/10^4$ yuan)
	Quantity (10^4 t)	Percentage in whole city(%)		Quantity (10^4 t)	Percentage (%)	
Whole city	5110.80	100.0	53.5	4084.59	79.9	2.89
Spinning	964.84	18.9	78.3	939.57	97.4	22.10
Electron and communication production	719.45	14.1	52.8	443.30	61.6	1.23
Electricity, stream and hot water	475.35	9.3	45.7	80.60	17.0	4.72
Plastic production	446.06	8.7	51.1	51.32	11.5	3.56
Metal	416.97	8.2	61.8	189.49	45.4	4.83
Electric machine	260.34	5.1	45.4	35.56	13.7	1.82
Clothe and other fiber	245.81	4.8	49.5	83.72	34.1	3.22

Most barbershops discharge the waste water into the sewers directly, and their average waste water discharge per output is the largest. Though it is not the largest water consuming sector, because there are a lot of such enterprises and their distribution is very dispersive; their waste water treatment situation is the worst, and they have polluted the environment considerably.

The largest waste water treatment rate in the tertiary industry lies in health sector, which is up to 83.6%. The main pollutants in the industrial waste water industry are COD and SS. The main pollutants in waste water of the tertiary industry are animal and plant oil, BOD and COD.

Table 14 Waste water discharge in different sectors of the tertiary industry

Sectors	Waste water discharge		Percentage of waste water conversion (%)	Waste water treatment		Waste water discharge ($t/10^4$ yuan)
	Quantity (10^4 t)	Percentage in whole city(%)		Quantity (10^4 t)	Percentage (%)	
Whole city	2830.53	100.0	88.1	758.46	26.8	29.56
Food	1236.86	43.7	91.8	300.80	24.3	34.95
Hotel	978.27	34.6	93.0	250.06	25.6	39.49
Hairdresser and cosmetic	247.53	8.7	90.0	8.68	3.5	63.63
Recreation	189.84	6.7	90.9	71.87	37.9	28.89
Sanitation	152.04	5.4	51.4	127.05	83.6	12.60

4.5 Solid waste and noise

Solid wastes discharged from the secondary industry include ganjue, boiler residue, color metal residue, industry waste, dangerous waste and so on, as well as domestic waste and hospital waste of the tertiary industry, and their percentages are 79.1% and 20.9% respectively. The discharge rate is 9.4% (discharge quantity divided by producing quantity). The secondary industry produced 92.9% of dangerous waste and the tertiary produced 7.1%. The discharge rate of dangerous wastes is 0.9%. The comprehensive utilization rate of wastes in Shenzhen is 58.2%. There is no comprehensive utilization in the tertiary industry solid wastes, however, it is 73.6% in the secondary industry. The total waste disposal quantity is 1.824×10^4 t, and disposal rate is 35.3%. The domestic wastes are disposed of completely, and the disposal rate in the secondary industry is 18.2%.The distribution of solid waste is shown in Table 15. Compared to the tertiary industry, the three noise sources in the secondary industry are much larger. There is 77.9% in the secondary industry and only 22.1% in the tertiary industry.

Table 15 Distribution of the secondary and tertiary industry solid wastes in Shenzhen

District	Soild waste produced(10^4 t)		Comprehensive exploitation of solid waste(10^4 t)		Solid waste discharge (10^4 t)		Dangerous solid waste discharge (t)		Solid waste disposed (10^4 t)	
	Quantity	Dangerous solid waste	(10^4 t)	Exploitation percentage (%)	(10^4 t)	Discharge percentage (%)	(10^4 t)	Discharge percentage (%)	(10^4 t)	Disposed percentage (%)
Whole city	40.88	0.92	30.08	73.6	3.37	8.2	93.16	1.0	7.43	18.2
Luohu	1.11	0.06	0.90	81.1	0.06	5.4	12.01	0.0	0.15	13.4
Futian	1.44	0.24	1.01	70.1	0.12	8.3	2.00	0.1	0.31	21.5
Nanshan	28.43	0.23	23.80	83.7	0.25	0.9	14.02	0.6	4.38	15.4
Baoan	3.91	0.04	2.27	58.1	1.33	34.0	53.63	13.4	0.30	7.7
Longgan	5.98	0.35	2.10	37.4	1.60	26.8	11.50	0.3	2.28	38.1

Table 16 Quantity of three different noise sources in Shenzhen

	Whole city		Secondary industry	Tertiary industry
	quantity	percentage		
Generator	6793	11.3	6423	370
Cooling tower	5523	9.1	4649	874
Deflating machine	48050	79.6	35933	12117
Total	60366	100	47005	13361

4.6 Dynamic Changes of Environmental Pollution in Shenzhen City

Before 1979, Shenzhen was mainly an agricultural industry. The vehicle transport had not been developed, each kind of energy consumption was low and pollutant emission was largely below the natural purifying capacity. So the environmental quality of Shenzhen City was better at that time. In the following 20 years, with the rapid development of economy, environment pollution changed correspondingly. Pollution of air, water and solid waste increased in different districts. According to incomplete investigation and observation, we can analyze as following:

Table 17 Environmental pollution change of Shenzhen Special Economic Zone, 1984 - 1996

Year	Waste water discharge in Special Zone (100 million tons)	Waste gas emission in Special Zone (100 million m^3)	SO_2 emission in Special Zone (ton)	Industrial solid waste discharge in Special Zone (ton)
1984	0.35	2.4	110	2.0
1985	0.48	2.7	114	2.3
1986	0.72	19.7	415	2.5
1987	0.80	26.4	543	2.6
1988	1.04	32.1	685	2.4
1989	1.21	38.4	979	2.4
1990	1.37	21.5	466	2.2
1991	1.43	58.4	1356	3.5
1992	1.74	69.1	1702	4.8
1993	2.19	293.1	3317	11.1
1994	2.61	276.1	10774	20.1
1995	2.7	249.6	12675	23.5
1996	2.85	316.0	17941	29.2
1997	3.00	305.7	18916	34.3
1998	3.32	458.3	21410	31.3
1989/ 1984	3.46	16.0	8.9	1.2
1998/ 1984	9.49	191.0	194.6	15.7

Note:1984 as the base 1

Table 17 shows the change of main pollution indexes in Shenzhen Special Zone from 1984 to 1998. From the table we can see that, air pollution, water pollution and solid waste pollution all show a clear rising trend. Among them, waste gas emission increased by over 191.0 times, waste water discharge by 9.49 times, SO_2 emission by 194.6 times and the emission of the industrial solid waste by 15.7 times. From a view of the city as a whole, ecological environmental degeneration out of the Special Zone has intensified clearly; air quality of the city has decreased, which is represented by the descended quality of coastal water and deterioration of many rivers.

5. Main Countermeasures to Environmental Management in Shenzhen City

5.1 Environmental policy of the Chinese government

- Put prevention first, combined with treatment. This policy is made according to the large scale economic construction. At the same time, prevention and treatment of environmental pollution and damage is very important. In the last 40 years of development, some environmental pollution and damage were caused and must be controlled actively. The main measures include bringing environmental protection into middle and long phase plans and annual economic social development plans at national, local and industrial levels as well as development and construction projects; environmental effect evaluations and "three same time" will be implemented(facilities for preventing environmental protection and damage planned, constructed and operated with main works production at the same time).

- Who pollutes, who manages. This policy is made according to the weak environmental consciousness that the responsibility of pollution control is usually with the government and society. It has three aspects. The first is that transformation, prevention and treatment of industrial pollution are combined with technology. It is provided that during the process of technology transformation, pollution control must be considered as a main goal and the expenditure can't be lower than 7% of the total. The pollution of some factories and mines left by history will be controlled within a definite time, and its expenditure will be collected by industry and the local government. The central government will give a little aid. Emitting pollutants will be charged, and the money will be saved as the special fund by local governments to control environmental pollution.

- Strengthen environmental management. The main measures are as follows. Making laws and standards: At present, the nation has issued 4 special laws on environmental protection(the law of environmental protection, the law of prevention and cure of water pollution, the law on prevention and treatment of air pollution, the law of prevention and treatment of solid wastes), 8 relative laws, about 20 administrative laws and about 230 environmental standards. The environmental law system has been established initially. Also the execution of environmental laws has been enhanced continually. The four level governments from central authorities to province, city and county set up environment management institutions. As the State Council adjusted institutions in 1998, the former State Environmental Protection Bureau was promoted to General Bureau of State Environmental Protection (an institution of ministry degree). Now about 2000 environmental monitoring stations have been set up and the environmental management personnel are more than 70 thousand people. The first measure is to pursue two environmental management rules. One of them is the environmental goal responsibility system according to the important role of local government leaders in environmental quality's improvement. Environmental goals are prescribed for leaders at each level in their tenure of office. Each year they will announce the executing schedule, which will be regarded as a content for judging their achievements in their official career. The second is the quantitative check system of urban environment synthetic control. The city is a center of population and industry, and also the area where pollution is serious and the important point of environmental protection in China. In order to check the condition of urban environmental protection, 20 indexes about urban environment quality and environmental protection have been made and testified each year. The result is announced to the public and regarded as a content of checking achievements in their official career. In recent years, the system of choosing "environmental protection model city" has developed, which improves the work of urban environment protection. Beside the above three policies, the Central Government has worked out 8 rules of environmental protection according to the greatness of the work. The national strategies of sustainable development and the change of inefficient use of resources to highly efficient use are certain to be carried out . At the same time, the whole country's engineering of overall control towards serious environmental pollution has developed, such as "one o'clock activity", to controll the standard discharge into Huai River, Tai Lake and Dian Lake.

5. 2 Environmental policy of the Shenzhen government

Through the environmental policies issued by the Shenzhen government during the 20 years since establishment, three aspects can be summarized:

- Implement each national environment protection policy. Since the national environment protection policy in China is formulated by governments at each level, the government of Shenzhen City must implement entirely each national environment protection policy. In this respect, the Shenzhen Special Zone has no special policy. The above three policies have been implemented in Shenzhen. The main works in the new year ascertained by the government report each year all include "synthetic control of ecological environment" and ensure concrete measures.
- Implement environmental protection laws of the Special Zone and strengthen the environmental management. Taking advantage of the authority of "legislative power in the Special Zone", Shenzhen City developed a series of environmental protection laws. In addition, the government also implemented relative environmental quality standards of the nation and Guangdong Province. In 1977, "Environmental function zoning of coastal seas in Shenzhen" and "Plan of total pollutant emission control of Shenzhen City" were worked out.
- Strengthen the investment intensity in environmental protection engineering and improve the construction of environment facilities. The investment into environmental protection of the city in 1998 was 2.31 billion RMB, 1.79% of the gross value of the domestic products, which exceeded the average of the country (0.7% - 0.8%). The main constructions were engineerings of water source protection, waste water treatment, waste water discharge to the sea, garbage disposal, solid waste filling, water and soil reservation as well as transportation and roads.

5.3 Environmental measurement of pollutant emission industry

Regardless of the total investment or operating cost, the industry occupied 90% and the tertiary industry 10%. Compared with developed countries, the rate of environment control investment is clearly lower. The investment in environmental protection facilities of the industry is 0.88% of the fixed assets, which is lower than the 5-8% standard of "environmental protection investment of the total investment". This shows industrial enterprises of the city pay little attention to environmental protection in their plans for production. The annual operating cost of environmental protection is less than 0.1% of the total output value (actually 0.08%). The input of the operating cost is seriously inadequate.

The total environmental control investment of the tertiary industry is inadequate and the level of technology control is very backward. The treatment facilities of restaurants and hotels are only aparete oil pools and pipes, not having a real purifying process for the waste water. The industrial enterprises which are examined and approved by the environmental protection agencies are only 28%, while the counterpart of the tertiary industry is 16%.

6. Experiences and Lessons of Environmental Management in Shenzhen City

6.1 Experience of Environmental Management

6.1.1 Privilege of local laws

The developments of environment and of economy in the process of urbanization of Shenzhen have been mutually interactive. Since 1980, when Shenzhen Special Economic Zone was established by law, the last two decades saw a coordinated progress in environmental management—protection and economic development. And the city environmental management since 1990 has been systematized. This is largely due to the fact that the special zone enjoys the privilege of passing its own local laws. Because of this privilege, Shenzhen has established a set of laws concerning administrative rules and regulations in general and environmental management in particular. These rules have been proved to be powerful in practice.

Environmental legislation has been an important focus in the municipal government's agenda. The bureau of environment protection established a department responsible for preparing and coordinating new rules. Together with the legal system bureau, the public security bureau, city construction bureau and other municipal departments, they succeeded in introducing a series of environmental laws in a short period of time.[1]

[1] They include Stipulations on Environmental Protection of Shenzhen Special Economic Zone, Regulations on Guarding against Noise Pollution in Shenzhen Economic Zone, Stipulations on Protection of Potable Water Source, Ordinances on Security and Environment Protection in the Surrounding Area of Dayawan Nuclear Power Station, Rules for Applying the National Environmental Protection Law on Solid Pollutants in Shenzhen, Stipulations on Water and Soil Preservation in Shenzhen, and regulations on city gardening. Shenzhen government also enacted Regulations on City Greening, Rules on Controlling Automobile Exhaustion Pollution in Shenzhen, Provisional Rules on City Drainage, Rules on Management of Construction Site.

6.1.2 Systematical environmental administration in Shenzhen's urbanization

The environmental management system in Shenzhen relies mainly on administrative measures, the effect of which will decides the successfulness of the environmental management. The present focus lies on a comprehensive decision making system to obtain sustainable economic growth. The system aims at applying environment protection to all economic and social decision-making as a criterion against which the quality, level and progress of social and economic projects can be measured. In making environmental management plans, setting up objectives becomes the first and foremost task.

Management and supervision of the environment are carried out by the governmental departments of the city and districts. The municipal government is responsible for macro management and decision-making. The environment department is in charge of daily affairs and works in coordination with other governmental departments, such as departments of city construction, traffic, public security, health, and those in charge of natural resources.

The main responsibilities of the environmental protection bureau are:

- Preparing laws and regulations on environmental protection in Shenzhen;
- Preparing plans for environmental control and supervising evaluations on building constructions which may have effects on the environment.
- Enforcing environmental regulations, collecting charges on discharging pollutants, researching into environmental issues, organizing ecological education and propaganda, and coordinating cooperation with other regions.

The administrative system of environmental protection in Shenzhen has the distinguished and improved features compared with other regions:

❑ Joint conference on environmental protection. According to the regulations on environmental protection of Shenzhen, decisions made by local governments at all levels must take into consideration environmental consequences, and must propose technical objectives and measures to prevent negative effects. In preparing programs for exploring land and city plans, evaluation of environmental consequences must be made. Such evaluation is not limited to building constructions. It is applicable to the exploration of natural resources and to the making of all social and economic decisions and plans whose consequences may have a bearing on the environment.

The environmental bureau has the right to veto projects which damage the environment. The municipal government publishes every six-month Index for Guiding Investment in Shenzhen, in which are listed categories detrimental to the environment. Investment projects falling into these categories are subject to examination and approval by the bureau.

Waste Packaging and Collection, Notice on Using Automobile Horns, and specifications for standards and classifications for protection of potable water and for noise pollution.

Previously, only the municipal government had the power to order enterprises to finish renovation within a given period of time if these enterprises violated environmental regulations. If these enterprises failed to renovate, they could be ordered to close their business. Now this power is given to district and sub-district offices in dealing with local enterprises. Only those enterprises who belong to national ministries and provinces are left to the municipal bureau to be dealt with.

- Collection of sewage charge and ecological compensation fee. Compared with the national standards, Shenzhen charges a higher amount in this regard. The city announced the principle of "sewage charge exceeding compensation." The environmental bureau also charges on relevant enterprises an ecological compensation fee which does not exempt these enterprises from their responsibilities for preventing pollution. A sewage discharge permit should be applied by all companies involved in the discharge of waste water and gas. The expiration time of the permit is limited to a five-year period. If enterprises fail to meet the criteria set up in the permit, they will be charged a penalty fee. The issuing of the permit established a deal with waste discharge.

- Community supervision. Shenzhen made use of the practice in Hong Kong to introduce community supervision in controlling automobile exhaust. The public traffic department engaged citizens as supervisors. These citizens, after appropriate training, are responsible for reporting automobiles that are tailed with black smoke.

6.1.3 The main advanced technology of environmental protection

- Waste water treatment technology

The water quality pollution of earth surface and coastal water is a serious environmental problem in Shenzhen City. The main technologies taken by Shenzhen to solve the water pollution are:

- Invest capital in constructing the big waste water treatment factory to process waste water collectively.
- Discharge industrial waste water according to the criteria and control the total based on density control.
- Construct sea discharge engineering to discharge into the deep sea the treated urban waste water and industrial waste water reaching the standard.
- Quicken the construction of a complete set of municipal pipes to emit pollutants.
- Extend the use of small and miniature types of facilities for domestic sewage treatment in residential quarters.
- Develop the engineering of water sections and pollutant emissions along reservoirs. Cut waste water and lead it outside the river basin for treatment.
- Enforce the afforestation in the basin of the reservoir and prevent soil erosion and non-point-source pollution.

- Technology of reducing atmospheric pollution

Shenzhen City has one of the smallest air pollutant emissions per 10000 RMB among large medium-size cities of China. In 1996, the emission of SO_2 per 10000 RMB industrial output was 3000 g and the emission of smoke dust was 530 g, which was clearly below the level of the country.

The main measures in reducing air pollution taken by Shenzhen City are:

- Dispose energy structures reasonably, actively develop secondary energy to be clean and convenient, elevate the proportion of coal as secondary energy, such as electric power and heat power, and reduce direct and dispersed burning of raw coal.

- Limit the development of small enterprises with high-energy consumption in each kind of planning and examining of industrial items.

- Test waste exhaust control facilities of enterprises in certain intervals. Implement the work for reaching the standard.

- Renovate transportation, improve the conditions of the main line, and reduce the traffic exhaust emission due to the traffic jam.

- Enforce the supervision and management of traffic exhaust, popularize the technology of gas burning vehicles, and the use of non-lead gas through government subsidy.

- Technical analysis of environmental information management system in Shenzhen

As a special economic zone, Shenzhen stands in an avant-guard position in the country's social and economic development. Management of environment in Shenzhen features extensive application of modern information technology.

After conducting field research and surveys, we believe that the city environmental management in Shenzhen is becoming more and more effective, accurate and scientific by taking advantage of modern information technology. Two information systems can serve as good examples. One is the Shenzhen environmental information management system developed by the city environmental bureau. Another is the filing system of municipal drainage facilities developed by the city construction management office.

In June 1998, an investigation was conducted on the environmental information management system in the city environmental bureau. Experts and researchers on the project demonstrated the functions of the system. The system consisted of four sub-systems: an automatic system for monitoring air quality, a drainage charging system, a system of examining and approving environmental acceptability of planned building constructions and a pollution investigation system. It was completed in 1997. Now a network is being built to connect the system in the city bureau to district offices.

The city office spent 8 years building this system. Special software was developed and networks were constructed so as to make the retrieval of particular files convenient and fast.

- The layout and planning of urban land

Against the backdrop of rapid economic growth and population explosion, the municipal government has tried to make best use of city land and establish a sound ecological system. In planning the layout of the city, Shenzhen follows the principles below:

- Provide necessary space for building the city into an international metropolis.

Establish resource distribution and functional systems for sustainable social, economic and environmental development.

- Integrate and systematize city planning.

Based on these principles, the layout of the city consists of three pivotal lines, three circulars, three levels of city centers and nine functional communities. Industry-concentrated and polluting areas are located in the semi-pollution-sensitive regions. Except land preserved for agricultural protection, city development and construction, all the rest of the land (11.46 million square kilometers) has been arranged sensibly. Water source protection area of 840 thousand square kilometers is under strict environmental control. 76% of non-construction land will be used as ecological land as part of the overall ecological program. To prevent the disorder of land exploration and deterioration of city environment, 68 square kilometers of green fence will separate different functional communities. 31 places covering 41 square kilometers of land are allocated for tourism and recreation. There are 22 places (247 square kilometers) in the suburban area for outing. Land planned for ecological purpose covers 706 square kilometers. By 1997, trees were planted on all the naked land along the highways and main roads, or on naked hills and stone pits.

6.1.4 Take city infrastructure into account

Conditions of city infrastructure mark the success of environmental protection. Since the establishment of Shenzhen Special Zone, the local government has put heavy investment in the city's infrastructure. It is now of considerable scale and effectiveness.

❑ Facilities for disposing solid waste

- Shenzhen refuse incineration plant: built in 1988; investment totaling 47 million yuan; with advanced oversea equipment and a capacity for handling 450 tons of garbage per day.

- Yulongkeng and Nanshan refuse burial sites: completed in 1998; with the capacity for disposing 1600 tons and 450 tons of garbage respectively

- Xiaping refuse burial site: officially checked in 1998 according to international standards; planned capacity of 1800 tons per day.

- Shenzhen hazardous waste burial site: construction beginning in 1994 and yet to be completed; investment already amounting to 39 million yuan; first stage completed in May, 1995; effective capacity of 23 thousand cubic meters; first of its kind in the country.

- Shenzhen industrial waste disposing station: built in 1988 for hazardous industrial refuge. It can also reclaim usable resources. By the end of 1997, the station accumulated fixed assets of 17 million yuan and a production value of over 30 million yuan.

- Sewage treatment

Since 1983, Shenzhen has built Shekou District sewage treatment plant, Binhe water purification plant, Nanshan water purification plant, Boji Caopu sewage treatment plant, Bainikeng artificial pond. The investment of Boji Caopu plant amounted to 22 million yuan, with a capacity for treating 30,000 tons of sewage per day. Nearly 100 million yuan was invested in Bainikeng artificial pond, Shawan sewage disposal pump and Shiyan reservoir sewage treatment system.

In addition, Shenzhen has built 63 small sewage treatment facilities, the planned total capacity of which reaches 57.45 cubic meters. In reality, these facilities deal with household sewage of 2.7 cubic meters, which are 27% of the total sewage. They are the most advanced facilities in the country.

Projects in plan or preparation include: sewage treatment project supplemented by Nanshan sewage treatment plant, the planned investment of which amounts to 750 million yuan; Luofang sewage treatment plant, with a total investment of 350 million and a capacity of 30,000 tons; Pinghu sewage treatment plant; and the expansion of Shekou sewage treatment plant. When these projects are completed, the total capacity for handling sewage of the city will rise to 1.46 million cubic meters per day (the total amount of household sewage of the city are 1.71 million cubic meters).

- Traffic system

In order to ease the problems of traffic congestion, noise pollution and automobile exhaustion, Shenzhen has renovated roads, adding fences, traffic marks and lights, fly-overs, monitoring facilities, and parking lots. It has improved its traffic control by computer system. By 1997, the city rebuilt 16 main roads and forced over 1300 heavily polluting cars to be dumped.

- Drainage

Statistics show that before 1994 the total length of drainage pipes remained between 700—800 kilometers. Beginning in 1995, the construction of drainage pipes increased rapidly, extending to 1746 kilometers in the same year, and to 2082 kilometers in 1996.

Also during the year 1995 and 1996, the constructions preventing floods and waterlog in Luohu sub-district and Meiling industrial district, the first stage of Shenzhen River renovation, renovations of Buji River, Futian District, Dasha River, Maozhou River were completed. These works improved living environment and brought soil erosion under effective control.

- Construction of urban green cover

Green cover was weak before the setting of Special Economic Zone, having only 8 kilometers of road tree, a poor reservoir park and a small forest field. As a result, dust blew everywhere and water sources were muddy. After the establishment of the Special Economic Zone, the Shenzhen government concentrated considerable resources in increasing green cover. As a result, the green cover ratio rise from 10% in 1982 to 44.0% in 1998, and the average personal public green cover rose from 2.5 m^2 in 1982 to 13.89 m^2 in 1998. In 1998, they were 47.4% and 44% respectively.

6.1.5 Environmental Investment of Shenzhen City

Investment in municipal works such as traffic, water supply, drainage facilities has been increasing annually in Shenzhen. By 1996, the city had realized investment of 135.507 billion yuan in fixed assets (not including the investment of 13.579 billion yuan in Dayawan Nuclear Power Plant, collective funds of 17.55 billion and a 100 million yuan investment by the state). More than 30% of this investment went to infrastructure construction. In 1997, investment of this kind increased again. The heavy investment in infrastructure of the city greatly improved the living environment, and quickened the process of urbanization of Shenzhen. It also invigorated investment in environmental protection. In 1996, the environmental investment of Shenzhen reached 1.77 billion yuan, or 1.86% of the GNP, 2.08 billion yuan in 1997, or 1.86% of the GNP and 2.31 billion yuan in 1998, 1.79% of the GNP. The annual increase of environmental investment of Shenzhen is the quickest in the country.

6.1.6 Education and awareness of environmental protection in Shenzhen

The special environment education institution—the center of environmental protection propaganda and education is established in the institutions directly under the environmental protection bureau of Shenzhen City. The main duty of this center is to develop environmental protection propaganda and education through various forms, rich content and distinct characteristics, and to take advantage of each kind of propaganda measure and news media sufficiently. These works can improve leaders' consciousness of environmental protection policy, sustainable development, synthesis decision of environment and development, environment administration and economy. They can also improve citizens', especially the young's, consciousness of environmental law, environmental technology, environmental civilization, environmental moral, environmental consumption, environmental literature and art.

A survey was conducted on Dec. 6, 1998, at several public places in Shenzhen. The survey group handed out 115 copies of questionnaire at random to local residents, and collected 110 valid copies.

It can be easily seen from the survey that local residents' awareness of environmental protection is high in Shenzhen. People from all walks of life are conscious of environmental protection being the most vital issue in their daily life. The evaluation of the local residents on present status of the environment and major problems is accurate and objective. The majority of local residents see the issue as one of protecting the whole ecological system. And some of them have realized the ultimate fate of the environmental problem lies in the contradiction between the environmental problem and economic development. This awareness will help promote active participation of the local residents in environmental protection, and facilitate the implementation of official environmental policies and regulations.

6.1.7 Environmental and economic policies in the process of urbanization

- Adjustment of industrial policy and structure

In the final analysis, the economic growth of a city is an optimization process of its economic structure and natural resources. The process of urbanization of Shenzhen underwent a period of industrial structural optimization. This optimization has played a key role in obtaining a sustainable economic city growth.

In its process of growing from a fishing village into a modern city, Shenzhen has been under constant industrial restructuring. The proportion of the tertiary industry has remained above 41%, which is two times higher than the national average. Entering the 1990s, Shenzhen outlined its economic strategy as "relying on high-tech, advanced industries and concentrating on the tertiary industry," and engaged in perfecting this strategy. It put emphasis on developing advanced industries which produce high quality, high-tech, energy-preserving and environment-friendly products.

In 1996, the ratios of three industries were 1.7:49.3:49.0. The energy consumed by the tertiary industry constitutes about 20% of the total, but the production value scored nearly 50%. Since 1992, the production value of high-tech industries has been increasing by 7% annually. In 1996, the production of PC, software, new material and energy, biological engineering and laser amounted to 34.76 billion yuan, or 28.73% of the total value of industrial output of the city. This figure is 20 points higher than the national average. It constitutes 40% of the total production value of high technology in Guangdong Province. Thanks to the optimization of industrial structure, Shenzhen gained enormous economic benefit. At the same time, it effectively brought industrial pollution under control. Also the quality of the environment was much improved. According to statistics, sewage discharge per10,000 yuan of output value was recorded as 5.4 tons and solid waste 0.05 ton, well below the national average figures. They indicated a harmonious co-development of economy and environmental protection.

- Adjustment of energy policy and structure

Energy is the driving force of city development. Energy policy and structure directly affect the environment as well as the efficiency and economic benefit of production. The municipal government has charted rational and feasible policies on energy supply and structure, and built up a system of resource-preserving economy in accordance with environmental protection. These policies aim at bringing pollution under control at its sources. Main policy measures include:

Expanding electricity supply by preference policies, opening up channels for collecting and circulating funds and for encouraging enterprises to buy shares of electricity companies.

Setting energy prices according to laws of value and average social profit, enabling the energy industry to gain sustainable development. The government sets maximum prices for energy products which are environment-friendly.

Limiting enterprises of high-consumption of energy and encouraging techonology-intense enterprises of low-consumption.

Encouraging the use of clean energy: electricity and oil products, etc. The consumption of coal has been greatly reduced, and the proportion of electricity and oil consumption has increased to over 90% of the total energy consumption of the city. This has greatly improved the air quality. Among 82 large and medium cities in the country, Shenzhen is the lowest in discharging air pollutants. In 1996, the amount of carbon dioxide discharged per 10,000 production value was 3 kilograms; smoke and dust discharged 0.53 grams. Both figures are well below the national average.

- Economic measures to motivate environment protection

An important measure in managing environmental protection is to encourage commodity consumption and production that are helpful to the environment. Main measures adopted by the municipal government include the collection of sewage charge and ecological compensation fee. Take sewage discharge as an example. In 1996, the city collected 61.66 million yuan for such discharge, 49 million of which were allocated to environmental protection. These measures played a positive role in guiding company activities and consumer expenditure. It is a good method of using market mechanism to promote environmental protection.

6.2 Lessons from Shenzhen's environmental management

6.2.1 Lessons from environmental legislation in Shenzhen

There had been a period of time in which the legislation of Shenzhen Special Zone neglected the protection of the environment and over-emphasized the importance of economic growth. A typical example is the administrative order No. 5 issued by the municipal government in Jan. 14, 1993. The order stated that except for a few kinds of listed building constructions, all such projects would be subjected to examination and approval first by the government departments of industrial and commercial management, and then by offices supervising the environment. This administrative order contradicts the *Environmental Protection Law of the People's Republic of China*, which stipulates that building constructions should be registered and examined by official offices of environmental supervision before they are submitted to industrial and commercial departments. The order changed the procedure of registration, turning pre-supervision into post-supervision of the possible effects of building construction on the environment. The No 5 administrative order was legitimate in the sense of the privilege the municipal government enjoys in setting up its own local laws and regulations. Yet in the light of the essence of the order, it repudiates the national environmental law, which advocates the principle of "prevention first" in environmental protection. The consequences of the order were detrimental: although the evaluation of possible effects on the environment was carried out, people tended to consider the process as part of the red tape, and the supervision on the environment was largely ignored.

The administrative order No. 5 exerted much negative influence on environmental legislation and taught us a great lesson. Shenzhen municipal government corrected the practice by issuing a new order on Nov. 20, 1993. It demands that all building projects which may affect the environment should be examined and approved by the bureau of environmental protection before they are registered with the industrial and commercial departments. Yet there were a few projects carried out in that period which so far are still not registered or included in the management and supervision of the environment.

This example teaches us that although Shenzhen Special Zone enjoys the privilege of setting up its own local laws, this privilege should be exercised with great caution in accordance with the principles of national laws.

6.2.2 Problems and difficulties in making environmental laws in Shenzhen

- Limitation of applicability

The applicability of environmental legislation of the special zones is limited within the zones' judicial areas which do not cover the entire administrative areas of the cities where special economic zones are located. For example, the city of Shenzhen consists of two administrative districts as well as the special economic zone. The special zone covers only 16.2% of the total administrative area of the city. In theory, legislation of the special zone is applicable only to the zone itself. The other three special economic zones have the same problem. Problems arise because environmental regulations are aimed at controlling and supervising the environment of the whole city, whereas in legal terms, they are not applicable to a large part of the city. To divide one city into two judicial areas poses many problems for controlling and supervising the environment of the whole city. In reality, the applicability of some of the regulations has to be extended beyond the boundary of the special zone. For example, *Stipulations for Protection of Potable Water Resource in Shenzhen* is applicable to Shawan, a region outside the zone but whose water resource is vital to the city. So in practice, the laws and regulations concerning environmental protection are being considered and followed by the two districts bordering the special zone in the city Shenzhen.

Strictly speaking, the two districts do not have to abide by the local laws and regulations of the special zone. There are two possible ways to solve this contradiction: to extend the special zone to include the two districts in Shenzhen so the entire city area becomes a special zone, and to endow the special zone with the right to extend some of the laws or regulations beyond the zone when it is seen appropriate. At present, we think to merge the two districts is a more practical way.

- Innovation of the environmental legislation of the special zone

Although to some extent the environmental legislation of Shenzhen is innovative, it is still advanced. In the process, it should take further efforts in drawing lessons from other countries and regions. Future environmental legislation should focus on systemization through which environmental control and supervision can be enhanced.

- Coordination between environmental legislation of Shenzhen and Hong Kong

The geographic, economic, cultural and environmental ties between Shenzhen and Hong Kong are very close. Therefore, attention should be paid to the problem of legal coordination between two regions. This may lay a good basis for coordinating environmental management and protection between different administrative areas.

7. Conclusion and Suggestion

7.1 Conclusion

Shenzhen is a proving ground in the Southeast coastal region where Chinese reform and opening policy is being practiced, and it is a coastal opening city with high-speed economic increments. The high speed economic development is mainly the result of the reform and opening policy of the special region, the geographic location that is close to Hong Kong and Macao, the exporting economy structure with great foreign investment and the advanced industrial structure.

The core of the driving force of environment problems in Shenzhen is the growth of urban population, the quick step of civilization and high-speed economic development. The increase of practical utilization of foreign investment and capital construction investment are the key factors. The environment pressure is related to the land use change in time and space, the increase of income per capita and civilization level, energy consumption, industrial production and foreign tourists. The land use change and energy consumption are especially key factors. The environment situation shows that the rivers and reservoirs were polluted, the air environment quality decreased, the coastal sea was seriously polluted, the acid rain and soil loss sharpened and the bare land area increased obviously. Generally speaking, the high speed economic development has not led to serious environment pollution, which is closely related to the industry structure and the recognition of environment management, especially the adjustment of industrial structure and the environment law of the special zone. The environment influence is mainly embodied in the reconstruction and destroying of the semitropical coastal ecosystem, the climate warming and drought of the city, the frequent floods and the decrease of air and water environment quality. The main pollutants in air are SO_2, smog, fluoride and industrial powder, and the main pollutants in water are organic compounds. There are three main environment policies: One is the execution of the environment policy and standards of the state and Guangdong Province; the second is the lawmaking of the special zone; and the third is the strengthening of environment management and the increase of environment protection investment, the advanced environment technology introduction and international cooperation, of which lawmaking and investment are the key factors.

Now is the critical moment for the development and environment protection of Shenzhen, and an important stage of environment control under the high speed economic development, for the policy makers and residents have paid more attention to the environment as a valuable resource. So the environment protection strategy of Shenzhen is to strengthen the synthetical control, which is like the construction mode of ecosystem engineering and ecological city advocated by the environment protection of Japan. According to this, measures such as the management and control of the polluted industry were strengthened and the industrial structure transformation was focused on. On the other hand, they strengthened the management of the tertiary industry, invested great capital to set up the high standard infrastructure for urban environment protection, attached importance to the total environment protection engineering construction which is mainly centralized in waste water control, water source protection, air quality control and soil erosion prevention to add the vegetation cover and protect the environment capacity.

7.2 Policy suggestion

7.2.1 Incorporation of city pollution control into market

The world economic development indicates that environmental pollution could decrease to a tolerable degree and the environment quality standard of a modern developed country could be stable, if the investment in pollution control occupied 1-%-2% of the GDP. The expense of city waste water and domestic garbage control needs 55 hundred million RMB during the ninth five year plan period in Shenzhen, and the total environment investment needs to reach 146 hundred million RMB which accounts for 2.5% of the GDP. It is not enough that the investment only comes from the government and the enterprises. The environment control fee should be made part of the production cost and endured by the consumer. But it is difficult to execute the actual environment protection policy. First, in the government running system, the department that manages the plan doesn't manage the investment; the department that controls the investment doesn't manage the construction; the department that manages the construction doesn't manage the operation, and the department that manages the operation doesn't manage the effect, so what should the environment management department do? It is an obvious example that the planning and construction of the city waste water control and the water source protection and utilization are managed discretely. There can be no obvious improvements in the city environment pollution control if this system is not changed. The effect will be better if city pollution control is put into the market and the environment establishment constructed by the government is handed over to the enterprises to manage and the pollution makers are asked to pay the running fee, and the environment management departments only take the management responsibility.

7.2.2 Stimulate the commercializing of environment resources

Environment is a resource, which should be a commodity, and a commodity has the features of value and price. The value of environment resource is indicated by the price of water resource, land use, discharge waste and control treatment. It is the government's behavior that the resource fee is demanded by national land, water conservancy and environment protection agencies. This is to say that the environment resources have not been pushed into market. How can environment resources be commercialized? We should regard the follow points:

- Evaluate and calculate the regional environment contents well and truly.

The long-term plan with united law effects should be worked out according to the environment content. Under the condition of leaving enough resources for the future, it is rational to configure the environment resources, see that environment resources are used with payment and the principle of public competition which makes the value and price correspond, and before the buyer and the seller obtain the certificate of waste discharge, they must receive the examination and approval of the environment protection agency.

- Collect the resource environment compensating fee and the environment tax.

We must hold on the principle of who does the developing and who does the protecting, who creates the pollution and who controls resource exploitation, and all the departments and individuals in charge of resource exploitation and environment resource use should pay the environment resource tax. At the same time, the environment pollution tax should be collected for products that do harm to the environment.

7.2.3 Strengthen the survey, waste fee collection and administrative punishment

Environment surveying is the eye and the ear of environment management. Improving the ability of the survey worker, introducing advanced instruments and equipment, creating a national survey net, increasing survey frequency and assuring survey quality are all important work. The survey of waste consistency, category, quantity and direction provides reliable data for administrative punishment and waste fee collection.

The waste fee and punishment must be greater than the pollution control fee, which can stimulate the enterprises to manage the pollution source self-consciously. The workers of the administrative and law executing departments must be disinterested and law abiding, able to adapt to the demand of environment management under the conditions of market economy.

7.2.4 Accelerate the construction of environment industry and assure the integrative control level

There are some experts who predict that the environment industry will be a main industry of China in the 21st century. Some developed countries are paying attention to the market of environment protection in China, so the environment department should make some policies beneficial to develop the environment industry and support a set of advanced technology industrys team to improve the environment protection industry system of study, consultation, design, construction and audit. The present status that the capital is not flowing, management is not perfect, the investment system is disordered and not effective because of the backward-looking policy, the backward technology and the bad design should be changed. The localism should be broken, and the advanced technology and equipment should be introduced to reduce the regional pollutant emission quantity to the least possible. A stitch in time saves nine, so it is vital to save the resources of the regional environment capacity.

7.2.5 Make the supervision system of the environment protection perfect and carry out the environment industry with Chinese characteristics

Since the Director General Qu Geping of the State Environment Protection Bureau created the environment management theory of China in the early 70's, the environment industry of China experienced the control of waste water, exhaust gas and waste residue and integrative management. Then it went to a stage in which economic development corresponded with environment protection. In the past 25 years, it set up a relative perfect law system and a team of environment protection technology and management, and made a series of Chinese characteristic policies and systems such as " three phases and three benefits, and policy system of the eight items". China takes the environment protection as the primary national policy.

We consider that the environment management in China is becoming better and better, and we will combine with the situation of China and try to study the advanced experience of other countries. First, it is necessary to make the management system perfect, overcome the multiple operation situations, and then strengthen the legislation and execution so as to push the environment protection system into legality.

7.2.6 Define the service value of the natural ecosystem

The service of natural ecosystem has value and can be priced. In the market economy system, regarding regional resource exploitation and utilization, the environment management must follow the principle of market economy. There are different types in the regional natural ecosystems, and the service values are not the same for different industry development stages. The service of the ecosystem is mainly to control the land degradation including water and soil loss, desertification and soil salinization in the agriculture stage. In the early industry stage, the service of the ecosystem is mainly to develop the natural resources by the function and structure of the vegetation to assure successful exploitation. The service of the ecosystem is mainly to clean the environment and control the occurrences and spreading of various environment pollution accidents that do harm to humans in the late industry stage, which was characterized by civilization and regional economic development. After the industry stage, the tertiary industry dominates in the region, and the service of the ecosystem is mainly to assure an environment secure for human survival. It is according to this that natural ecosystem protection must be considered in regional resource exploitation, which defines the service value of the natural ecosystem. The service of the natural ecosystem is limited in the region, which is to say that the environment capacity we can use is limited. Although human beings can change the service function of the local natural ecosystem to a direction beneficial for human survival, this change is very limited in fact. The service value of the natural ecosystem and the environment value are not defined in the present environment law of China. Any environment pollution behavior can impact the economy and human social development, so the control and management of the environment pollution will need more manpower, material resources and finance for support.

Therefore, it is suggested that the cost of the environment capacity and environment pollution control should be increased in product per unit in the present product price definition, and the cost of some environment pollution products used only by a few people should also be increased, which can assure that humans treat the environment equally. It is an effective measure for the pollution prevention fee to be taken into the product cost and the environment control fee to be raised higher than the waste discharge fee and administrative punishment fee to control the pollution economically.

7.2.7 Make an investment percentage of environment security construction

In the present condition, many departments pay less attention to protection and restoration, but more attention to exploitation, utilization and economic profits, which leads to the contradiction of regional sustainable development. So the investment percentage to assure the environment protection and resource exploitation at the same time in the regional resource exploitation must be emphasized. On the other hand, advocate the objective of transforming the city's entire environment management to the ecologic city and ecologic industry direction using the mode of city ecosystem protection, and then improve human behavior and consciousness of city environment protection. It is an obvious difference from the present mode which aims to control things after pollution. There is much investigation and research to be done in regional environment management under the market economic system.

References

1. Guangzhou Geography Institute, *Atlas of Shenzhen's Natural Resources and Economic Development*, Beijing, Science Press, 1985
2. Chen Tangyi, et.al., *Evaluation of Regional Environmental Impact and Study of Environmental Protection in Shenzhen Special Economic Zone*, Beijing, China Environmental Science Press, 1988
3. Environmental Protection Bureau of Shenzhen City, *Shenzhen Ninth Five-year and Year 2010 Environmental Protection Planning*, 1996
4. Environmental Protection Bureau of Shenzhen City, *Reports on Shenzhen Environmental Quality*,1990-1997
5. Environmental Protection Bureau of Nanshan District of Shenzhen City, *Planning Schene of Xili Water Source in Shenzhen,* 1995
6. Li Jinxun, Shi Peijun, *Theory and Practice of Regional Environmental Management*, Beijing, China Science and Technology Press, 1997
7. Environmental Protection Bureau of Shenzhen City, *Collection of Environmental Protection Regulations*, 1996
8. Qu Geping, *China's Environment and Development*, Beijing, China Environmental Science Press,1992
9. The State Planning Commission of China, et.al., *China Agenda 21st Century*, Beijing, China Environmental Science Press, 1994
10. Dong Suocheng, et.al., *The 21st Century Resource and Environment Strategy along China East Coastal Regions*, Beijing, Science Press,1996
11. *Yearbook of Shenzhen Real Estate*, Shenzhen, Sea and Sky Press, 1991-1993
12. *Yearbook of Shenzhen Real Estate*, Shenzhen, Sea and Sky Press, 1994-1995
13. *The Compilation Committee of Shenzhen Special Economic Zone Yearbook*, Shenzhen, Guangdong People Press,, 1985-1995
14. *The Compilation Committee of Shenzhen Statistic Information Yearbook*, Shenzhen Statistic Yearbook, Beijing, China Statistic Press, 1989-1998
15. Shi Peijun, Chenjin, Pan Yaozhong, et.al., *Shenzhen Urbanization and Environmental Security Construction*, Journal of Natural Resources, 14(4), Beijing, Science Press, 1999
16. Shi Peijun, Chenjin, Pan Yaozhong, et.al., *Study on Shenzhen Land-Use Change Mechanism*, Institute of Resources Science, Beijing Normal University, 1999
17. Chenjin, Ryo Fujikura, and Hidefumi Imura,*Study on the Relationship between Economic Development and Land-Use Change in Shenzhen City of China*, Insitute of Environmental Systems, kyushu University, Japan, 1998
18. World Resources Institute, et.al., World Resources(1996-1997), Oxford University Press, New York, Oxford, 1997
19. World Resources Institute, et.al., World Resources(1994-1995), Oxford University Press, New York, Oxford, 1996

Urban Environmental Management in Dalian City

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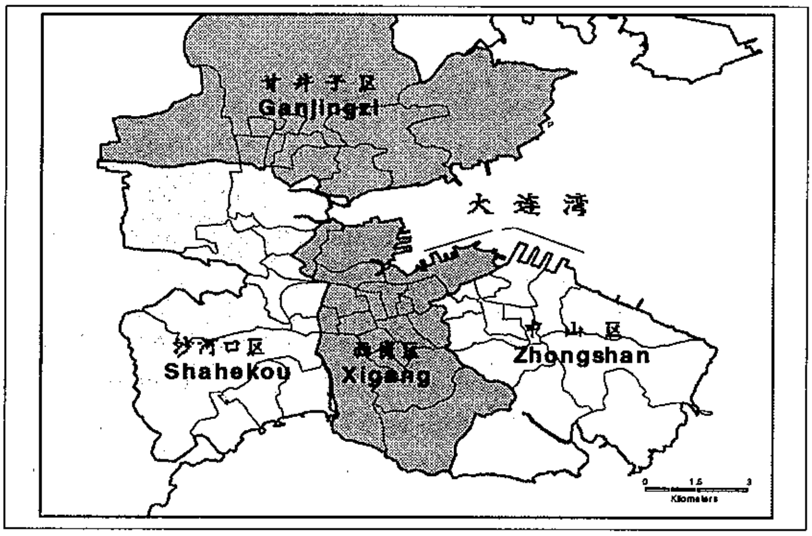
I. Basic Conditions of Dalian City

1.1 Location and Administration

Dalian City is located on the Liaodong Peninsula at the southernmost part of Southeastern China. The city lies at 120°58′ ~123°31′ E and 38°43′ ~40°10′ N. It is an important industrial and tourist port city. At present, Dalian City has six districts, three county-level municipalities and one county. The number of current population in Dalian is 5.404 million (urban population: 2.597 million and rural population: 2.807 million). The total land area of the city is 12,573.85 km^2, with the six districts covering 2,414.96 km^2, occupying 19.2% of the total land area. The total land size of the three municipalities and one county is 10158.89 km^2.

Figure 1-1 Map of Urban Districts in Dalian



Source: *Case Study Background Report of Dalian*, Beijing Normal University, 1999.

1.2 Natural Conditions

Dalian is located in the Temperate Zone of the Northern Hemisphere. The climate shows the characteristics of marine climate. The mean annual temperate is between 8.8℃- 10.5℃. The average annual precipitation is from 550-950mm, 60-70% in summer, about 3-5% in winter and spring. The mean annual wind speed is 4.8m/s in Dalian area and 5m/s in the urban section, with relatively strong wind and better diffusion. Temperature inversion is a weather phenomenon quite unfavorable for pollutant diffusion. Hence, it creates a great impact on the urban environmental quality.

1.3 Water resources

Generally speaking, water resources are relatively inadequate in Dalian, with a total amount of 5426 million m^3, of which surface water amounts to 4035 million m^3 and underground water is 1391 million m^3. The mean possession of water resources per person in Dalian is 848 m^3, which is only 31% of the country. The major rivers in Dalian include Biliu River, Fuzhou River, Dasha River, Zhuanghe River, Yinyna River, Fudu River, Huli River, Qingshui River and Dengsha River. The Biliu reservoir has over 100 million m^3 of water holding capacity, and is the primary water sources for Dalian City.

2. The Driving Forces for Urban Environmental Development of Dalian City

The main diving forces for urban environment development include population change, economic development, industrial growth, land use and urbanization, urban transportation, energy consumption and infrastructure construction. These factors (driving forces) are closely interrelated. Among them, urban population and economy are the two most important driving forces in Dalian.

2.1 Population and Urbanization Development

At the end of 1997, the population of Dalian was 5.4036 million, ranking second among all cities in Liaoning Province. The population growth rate in 1997 was 0.55%, 0.04% over that of the previous year. The average population density rate is 429.7 persons/ per square kilometer, while the rate in urban area is 1075.4 persons/ per square kilometer. Among the six districts in the urban area, the downtown Districts of Xigang and Shahekou have a higher population density.

When Dalian City was first established in 1903, the city's population was only above 40,000 people. By 1949, Dalian's population had grown to 2.5022 million, and this figure had reached 5.1344 million in 1989. The population increased very fast with an average annual growth of 2.63 percent, and the urban population also increased very rapidly, representing an average annual growth of 8.06 percent.

So the urbanization level increased rapidly, up from 22.3 percent in 1949 to 46 percent in 1989. Since the 1990s, the population increase has entered a comparatively steady period. From 1990 to 1997, it totaled 0.2256 million, with an average annual increase of 0.0282 million, which is only 42.86 percent of the corresponding indexes in the past 40 years. It shows that the urbanization in Dalian obviously slow down.

Table 2- 1 The Population Component of Dalian in 1997

	Population (person)	Share of Total Population (%)
Total Population	5,403,589	100.0
Urban Area	2,597,129	48.1
Counties & Municipalities	2,806,460	51.9
Male	2,742,147	50.7
Female	2,661,442	40.3
Agriculture	2,803,269	51.9
Non-Agriculture	2,600,320	48.1

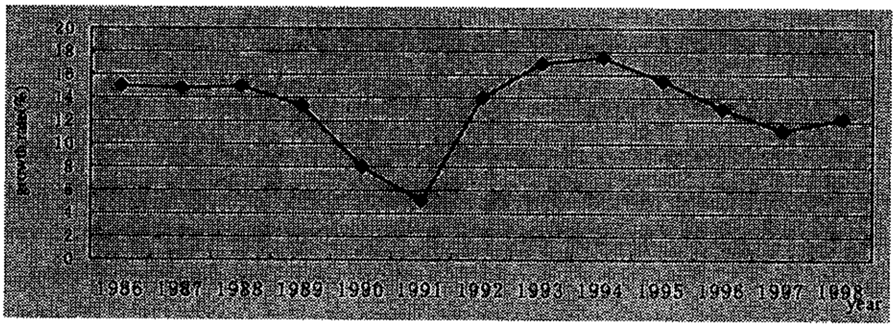
Source: *Dalian's Yearbook*, 1998.

2.2.Regional Economic Development

2.2.1 Economic Development

Dalian is one of the important industrial cities in Northern China. In 1984,Dalian became one of the first coastal cities that had initiated the open-door policy. It accelerated the pace of local economic development in Dalian. Now, Dalian's comprehensive economic strength ranks eight among all the provincial capitals as well as the cities with single planning status.

Figure 2- 1 Dalian's Economic Growth Rate, 1986-1998



Source: *Dalian Yearbook.*

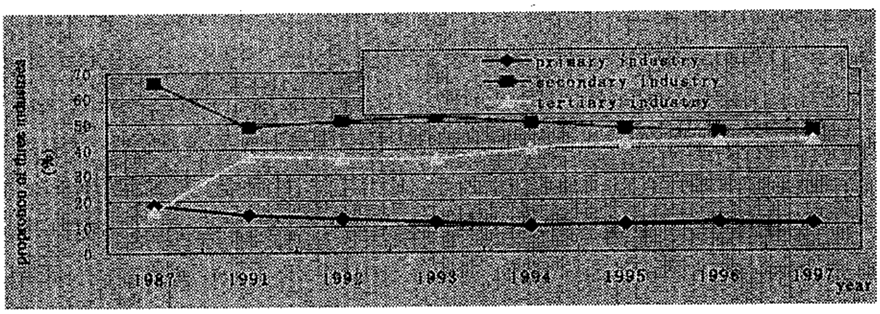
During the period of the Sixth Five-Year Plan (1980—1985), Dalian entered into a period of rapid economic growth, GNP increased from 4.93 billion yuan to 7.22 billion yuan, with an average annual growth of 8.1 percent. During the Seventh Five-Year Plan (1986-1990) period, Dalian maintained an even higher growth rate, an average annual growth of GNP reached 13.2 percent, up 5.1 percentage points than that of Sixth Five-Year peroid. During the Eighth Five-Year Plan (1991-1995), Dalian's economic development kept up its high growth trend, its GNP up from 21.922 billion yuan to 64.509 billion yuan by 1995, representing an annual GNP growth of 13.82 percent, 0.62 percentage points more than that of Five-Year Plan. Since the Ninth Five-Year Plan, although Dalian's economic development has somewhat slowed down, it has still maintained a relatively high growth rate. Its GNP increased from 73.31 billion yuan to 92.63 billion yuan, an average annual growth rate of 12.43 percent, slightly lower than that of the seventh and eighth five-year plans, yet still maintaining a growth rate of two-figure. The constant development and strengthening of the local economy are imposing a greater and greater pressure on its urban environment. Therefore, it is highly worthwhile to study and summarize Dalian's experience in realizing the "win-win" of both environmental protection and economic development. In the following parts, we will make a thorough analysis of this issue.

2.2.2. Economic Structure and Its Change

The proportion of the primary industry in the national economy has been decreasing year by year since the 1980s. However, the rate of decrease has been relatively steady and slow and become stabilized since 1994. The proportion of the secondary industry in the national economy dropped noticeably between the 1980s and the 1990s. Since entering the 1990s, this decline has slowed down. Between the 1980s and the 1990s,the tertiary industry developed rapidly with its proportion in the national economy also increasing rapidly. At present, in the components of Dalian's national economy, the secondary and the tertiary industries occupy a greater proportion, while that of the primary industry is comparatively less. In 1997, the GDPs of the three industries of Dalian increased 8.9 billion yuan, 38.7 billion yuan and 35.31 billion yuan respectively, which correspondingly took up 10.7 percent, 46.7 percent and 42.6 percent of the GDP of the year.

The 1980s saw a rapid growth in the economy of Dalian. Meanwhile, its economic structure also underwent adjustment from time to time. During this period, the changes of Dalian's economic structure showed the following characteristics. The proportions of the primary and secondary industries gradually and steadily decreased and that of the tertiary industry increased year after year. Compared with 1991, in 1987 the proportions of the primary and secondary industries dropped by 3.8 percent and 17.5 percent respectively, registering average annual decreases of 0.95 percent and 4.38 percent respectively. However, the proportion of the tertiary industry in the national economy rose by 21.3 percent, an average annual rise of 5.33 percent.

Figure 2-2 Dalian's Economic Structure and Its Changes



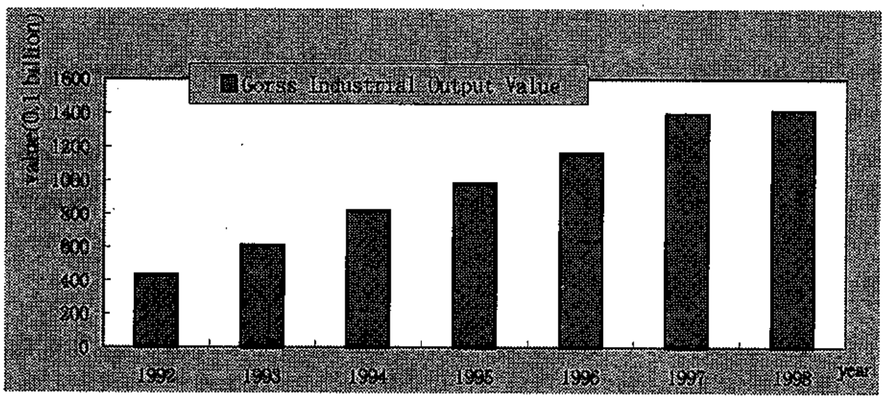
Source: *Dalian Yearbook.*

Since entering the 1990s, the proportions of the primary and secondary industries in the national economy continued to decrease, while that of the tertiary industry continued to increase, but with noticeable shrinkage in the volume of adjustments, and the economic structure began to stabilize. Compared with 1991,in 1997 the proportions of the primary and secondary industries in the national economy declined by 3.7 percent and 1.7 percent, showing average annual drops of only 0.62 percent and 0.28 percent. And the proportion of the tertiary industry in the national economy raised by 5.4 percent, an average annual rise of 0.9 percent. This indicates an obvious slowdown in the rate of the economic structure adjustments since the 1990s compared with that of the 1980s.

2.3 Urban Industry

The development and change of industries in the urban areas are the chief driving forces to the development and change of urban environment. As an important industrial city in Northern China, the development and change of Dalian's urban environment are closely related to the development of industries.

Figure 2- 3 Trend of Industrial Output Value



Source*: Dalian's Yearbook.*

In Dalian's national economy, industry always occupies an important position and the highest proportion. In 1998, Dalian's gross industrial product reached 141.37 billion yuan (at the consistent price of 1990), 15.1 percent more than 1997. In view of the past years' changes in Dalian's industrial products, Dalian has maintained a higher industrial growth rate.

During the Sixth Five-Year Plan, Dalian's gross industrial product increased from 7.55 billion yuan to 11.59 billion yuan, an average annual rise of 16.28 percent. During the Eighth Five-Year Plan, the growth rate averaged 26.5 percent. In 1995, the city's gross industrial output value amounted to 98.14 billion yuan. During the first three years of the Ninth Five-Year Plan(1996-1998), it maintained an average industrial growth rate of 19.77 percent, which, though a little slower than the previous period, still kept its high increasing tendency.

Such rapid development, while expanding industrial scales and increasing the sum total of economy, is bound to result in the increased consumption of materials and energy as well as the production of industrial wastes, thus composing a greater danger to the urban environment of Dalian. Therefore, industrial pollution has remained a key area in Dalian's urban environmental management.

In view of its industrial structure, Dalian's industrial structure has been developing and changing all the time. In 1998 in its gross industrial product, light industry took up 41.7 percent and heavy industry 59.3 percent. The proportion of light industry increased slightly, while the proportion of heavy industry decreased also slightly, with 3.1 percentage points respectively. Hence, heavy industry still occupies an important position in Dalian's economy (occupies about 60% of Dalain's industry).

Concerning actual output value of each major industrial sectors in the past years, the main eight leading manufacturing sectors in Dalian City include ordinary machinery, electronic and communication equipment, transportation equipment, electronic machinery and equipment, petroleum processing and coking industry, raw chemical materials and products, metalwork manufacturing, and non-metal mineral manufacturing.

2.4 Development of Township Enterprises

To some extent, in the control of industrial pollution, the status of the enterprises determines the enterprises' pollution behavior. Generally speaking, compared with foreign funded companies and state-owned enterprises of the same type, township enterprises pollute more seriously. Major reasons are: backward production techniques, small scope of the enterprises, lack of pollution management equipment, problems in supervision and management, and lack of environmental protection awareness on the part of the entrepreneurs.

At the end of the 1970s,Dalian's township enterprises have entered a real developing period. During the Sixth Five-Year Plan, these enterprises were still in their initial developing stage. During the Seventh Five-Year Plan, township enterprises began to enter a period of rapid development, township enterprises grew from 15846 to 20933, and their gross output value increased from 2.375 billion yuan to 6.203 billion yuan, respectively taking up 18.1 percent and 30.7 percent of the city's gross industrial product in the same year. During the Eighth Five-Year Plan, township enterprises in Dalian continued its rapid development. On an average, their industrial products increased by 61.4 percent annually. By the end of the Eighth Five-Year Plan, the number of enterprises had increased by 12.9 times over 1980 and by 1.1 times over the end of the Seventh Five-Year Plan. In 1993,proportion of industrial products of the township enterprises in Dalian's gross industrial product exceeded 50 percent and in 1996 it reached 62.7 percent. Township enterprises are becoming more and more important in Dalian's national economy, especially in its industrial development. By the end of 1997, township enterprises had totaled 128823, with a gross industrial output value of 87.35 billion yuan (at the unchanged prices in 1990), up 20.8 percent on the previous year. They had gained a net growth of 6.77 billion yuan, which took up 39.8 percent of the city's gross net industrial growth. Their developing speed is much faster than that of the other fields in the national economy. The rapid development of Dalian's township enterprises, while developing and strengthening the local economy, is imposing a greater pressure on the local environment. No doubt, the development of township enterprises creates a big challenge to Dalian's urban environmental protection.

2.5 Agriculture

Although the proportion of agriculture in Dalian's national economy structure is about only 10 percent, it occupies a comparatively important position. Concerning the agricultural activities of Dalian, the factors, which significantly affect the environment, mainly include pesticide, chemical fertilizer, plastic film, sea breeding, etc.

Table 2- 2 The Amount of Four Agricultural Factors in Dalian

Year	Pesticide (ton/year)	Fertilizer (10,000ton/ year)	Plastic Land Film (ton/year)	Sea Breeding (10,000ton/Year)
1980	-	49.83		—
1982	10635	-	1119	—
1986	2890	31.47*	—	22.7
1988	4081	-	669	40.4
1990	3211	43.10	573	48.0
1994	6547	27.66**	517	67.3
1998	9041	52.09	2205	96.0

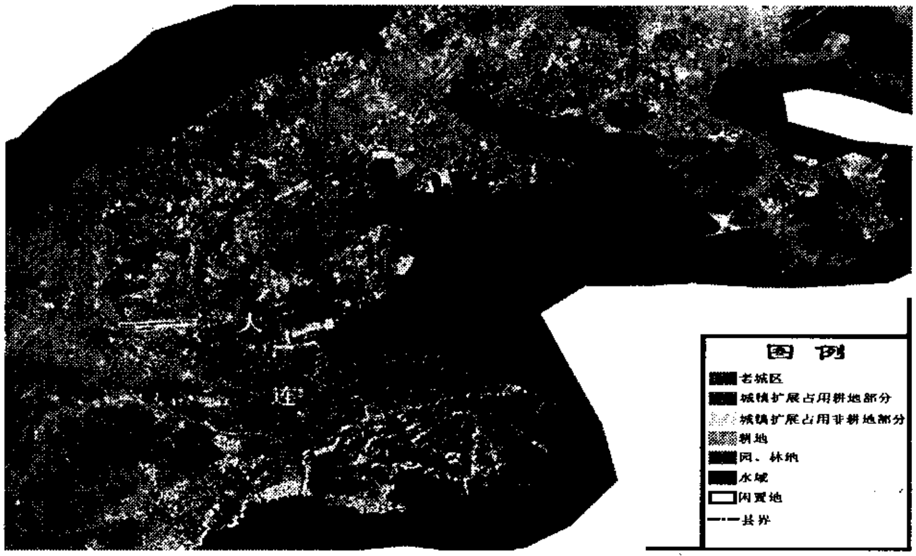
Note: 1. The data are taken from *Dalian's Agricultural Ecological Environmental Investigation,* 1995: Dalian Environmental Research Institute, and *Dalian's Yearbook; 2* The data* are the average amount in the Seventh Five-Year Plan, and **the average amount in the Eighth Five-Year Plan.

2.6 Land Use and Urbanization

The total area of Dalian City is 12,573.85 square kilometers, among which lands for urban construction mount to 4.498.16 square kilometers, 35.77% of the total area. Apart from the increase of urban population, outstanding features of urbanization also include the changing of land use, especially the increase of land for urban usage.

The Institute of Resources Sciences Research of Beijing Normal University conducted a dynamic monitoring of the land expansion for cities and towns' uses between Oct. 1990-Apr. 1997, employing remote sensing photos of satellite. The result shows that Dalian's total land expansion for cities and towns' uses amounted to 40796.7 m^2, taking up 14.68% of the total area of the constructed areas. Among the expansion, the four urban districts of Dalian rests at 11974.2 m^2, constituting 5.68% of the total constructed area in Dalian's administrative districts. Obviously, the expansion speed of the downtown area is relatively slow, while that of the city's outskirts is comparatively fast. The study also indicates that among the total land expansion in Dalian, 41.5% of that occupied farming land and 58.5% of that occupied land of other types.

Figure 2- 4 Dynamic monitoring map of urbanization (1990.10-1997.4)[1]



Source: "Case Study Background Report of Dalian", Beijing Nomal University, 1999.
1. based on classification of the TM image

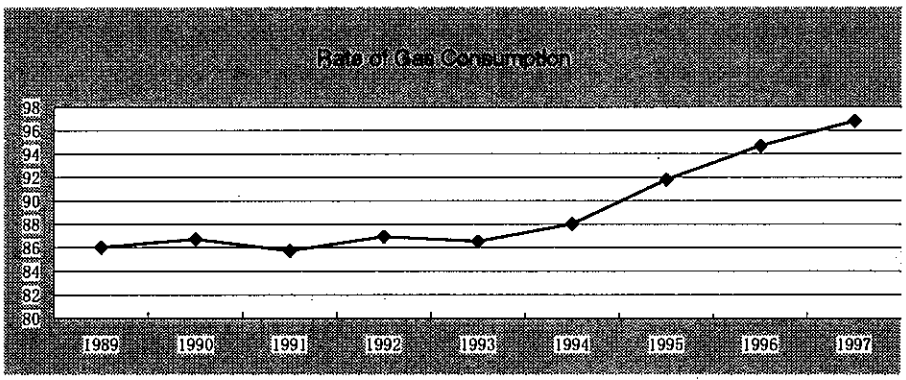
2.7 Urban Transportation

Urban transportation is an important factor affecting urban environmental quality. Studies in recent years show that transportation is contributing more and more to urban air pollution. The road traffic system of Dalian City is becoming more perfect day by day. At the end of 1997, it had a total road length of 1094 km, a road area of 1162 km^2 and 179 bridges. The road network density of Dalian is 3.85 km/ km^2。 In 1997, Dalian's motor vehicles totaled 2.343 million, 3.1 times that of 1978 and an average annual increase of 12.7 percent. The passenger traffic volume of that year was 84.53 million person-times and the freight traffic volume was 3273.67 million tons. The former increased by 11.42 million person-times and the latter decreased by 165.37 million tons compared with 1993. The impact on urban environment of road transportation mainly manifests itself in the area of motor vehicle waste gas, as well as of the traffic. Sea transportation occupies an important position in Dalian's urban transportation. Dalian port is the second largest port and also the biggest petroleum export port in China with a water area of 312.2 km^2 and a road area of 5.71 km^2. In 1997, it handled a passenger traffic volume of 5.29 million person-times and a freight traffic volume of 30392.66 million tons. Dalian Railway Station, located at the center of the city, completed a passenger traffic volume of 18.88 million person-times and a freight traffic volume of 12866.64 million tons in 1997. Dalian civil airport is the first international airport in the northeastern part of China. In 1997, it handled a passenger volume of 0.80 million person-times and a freight traffic volume of 15.64millin tons.

2.8 Urban Energy Consumption

Dalian's industrial energy consumption is mainly composed of coal consumption. The proportion of fuel coal in the energy resources has also been decreasing. In 1996, the industrial energy consumption of Dalian totaled 6.777 million tons of standard coal, 59.5 percent of which was fuel coal consumption. As there are numerous old enterprises in Dalian, a heavy task to save industrial energy and reduce energy consumption has always remained. Therefore, Dalian has been trying hard to reduce its industrial energy consumption through raising the energy utilization efficiency, improving and upgrading the production expertise, adjusting the industrial structure and so on. In 1980, Dalian's general energy consumption for 10.000 yuan output value was 6.34 tons of standard coal, which was reduced to 4.79 tons in 1985 showing an average annual decrease of 5.5 percent. During 1986—1989, this index continued to decrease, down from 4.38 tons in 1986 to 3.83 tons in 1989, registering an average annual decrease of 0.50 percent.

Figure 2- 5 The Changes of Household Energy Consumption in Dalian, 1989-1997



The household energy consumption of Dalian City is mainly composed of electricity, gas and coal. Table 17 shows the urban consumption of electricity, gas and others. Statistics show that the consumption of gas and electricity in the urban area has been increasing year after year. Compared with the figures in 1989, they increased by 23.7 percent and 229.5 percent respectively.

3. Pressure and State of Urban Environment in Dalian

3.1 Economic and Social Pressure on Urban Environment

Owing to historical reasons, Dalian's industries (including many heavy industry enterprises) are mainly located in the four downtown districts with mixed land use of residential and commercial areas. So the industries distribution is not good. What's more, of all the four districts, the enterprises are crowded in Ganjingzi District, causing serious environmental problems there.

Table 3- 1 Location of Industrial Enterprises in Dalian, 1993

District	No. of Enterprises	Gross Industrial Output Value (Billion Yuan)
Ganjingzi District	82	13.180
ShaheziDistrict	81	5.586
Xigang District	40	3.097
Zhongshan District	35	2.148
Jingang District	66	1.364
Lushunkou District	29	0.585

Source: *Dalian's Yearbook.*

3.1.1 Urban Water Supply

According to the statistics in Dalian's Yearbook, by the end of 1997, the total urban water supply for Dalian had amounted to 314,43 million m^3, in which household water supply was at 1.3669 m^3 occupying 43.5 percent of the total sum. During 1989—1997, Dalian's urban water supply increased by 103.2 percent and that of the household water increased by 145.4 percent. The increase rate of household water supply exceeded that for industrial and other uses. The growth of household water consumption was partly due to the expansion of the tap water network service of the city, partly due to the increases of the population and the per capita mean water consumption.

3.2 Pressure from Pollution

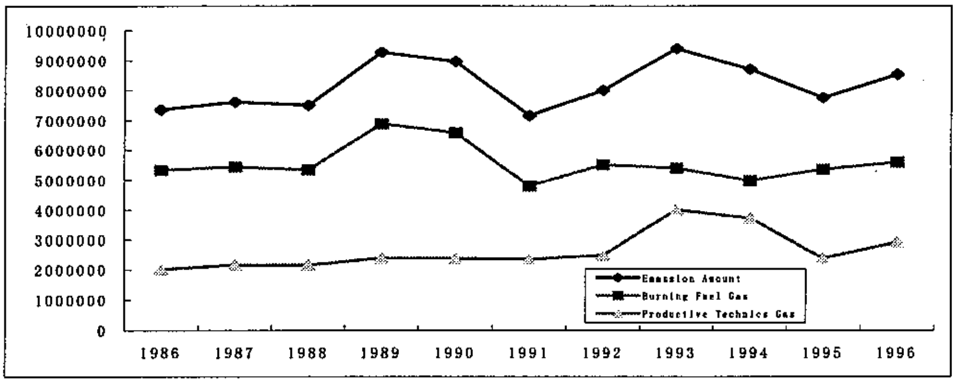
Environmental quality changes of Dalian City are closely related to the amount of pollutants emitted as well as other economic and social pressures. The increased amount of emission is exerting a growing pressure on the urban environment. In this part we will make an analytical study of the major environmental problems existing in Dalian City by investigating pollutant emission and its effect on the environmental quality.

3.2.1. Atmospheric Pollutant Emission and Its Main Sources

On the whole, air pollutant emission of Dalian City shows an ascending trend. In 1996, a total amount of 101,040 million cubic meters of waste gas was emitted, of which there was an amount of 84041,57 million cubic meters of industrial waste gas, which took up 83.2% of the total sum. Compared with 1992, the total waste gas emission rose by 12.2%, with an annual growth rate of 3.03%. Meanwhile, industrial dust emission, at 33,000 tons, decreased by 21,000 tons compared with 1992, with an annual decrease rate of 15.9%.In Dalian, the leading air pollutants are SO2, fume and industrial dusts, mainly produced in the fields of power industry, gas industry, metallurgical industry and cement manufacturing.

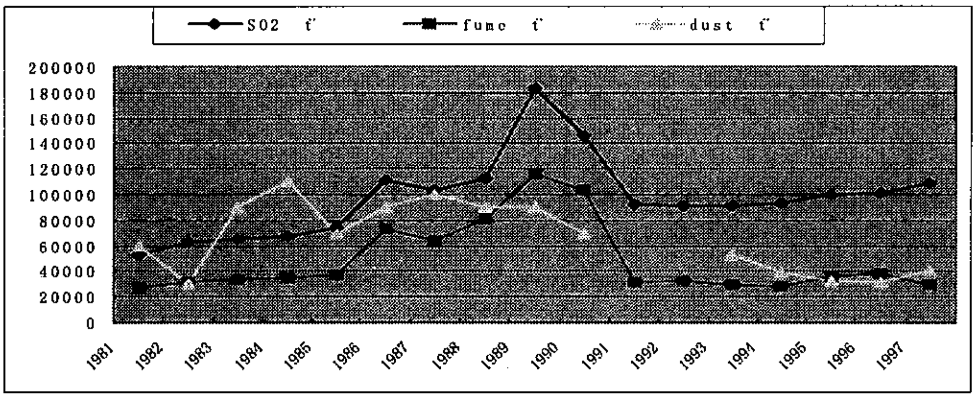
From 1981 to 1990, the total annual emission of SO_2 raised from 52400 tones to 145789 tones, increasing 10376 tones per year; but from 1991 to 1997, the total annual emission of SO_2 raised from 91600 to 108999, increasing 2900 tones per year.

Figure 3- 1 Changes of the Industrial Gas Emission of Dalian



Note: data are from Environmental Quality Report of Dalian.

Figure 3- 2 The Changes of Key Air Pollutants Emissions from 1981-1997



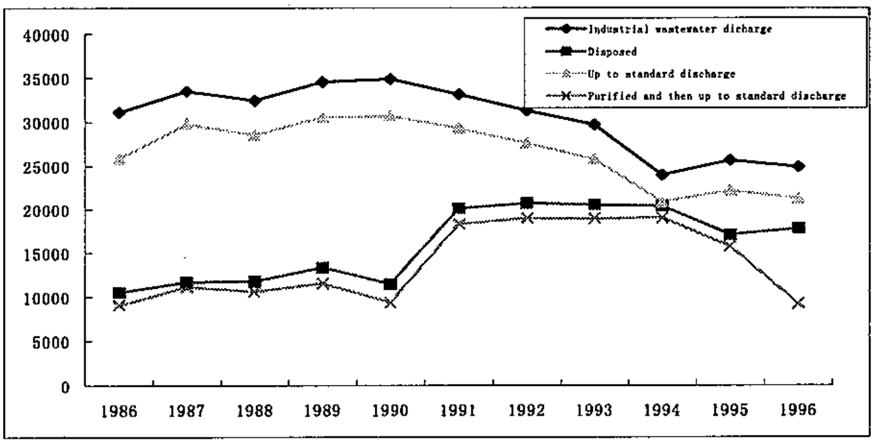
The sudden decrease of SO_2 emission was due to the economic decline and strict environmental management, and it also means that the effective control of air pollutants in Dalian was started from 1991. Comparing to the economic growth in the period from 1991-1997, the increasing (increasing rate is only about 3% from 1991-1997) of SO_2 emission is much slower than the economic growth. It is illustrated that the air pollution control comprehensive measures in Dalian decrease the pressures on environment.

3.2.2. Emission of Wastewater and Its Major Sources

Dalian's wastewater discharge is chiefly composed of living and industrial wastewater. Its main characteristics are as follows: discharge of wastewater from living is increasing year by year; And the main pollution comes from industrial wastewater, which, however, is showing an falling trend; the total amount of wastewater discharges is going down. In 1996, the total amount of industrial wastewater reached 339.72 million tones, occupying 73.1% of the total wastewater discharges.

Compared with 1992, the total discharge of wastewater has reduced 34,03 million tons, of which industrial wastewater discharge has reduced 64,38 million tons, showing a drop of 10.6 percentage points. The industrial wastewater discharge change condition in Dalian City during 1986-1996 is shown in Figure 3-3.

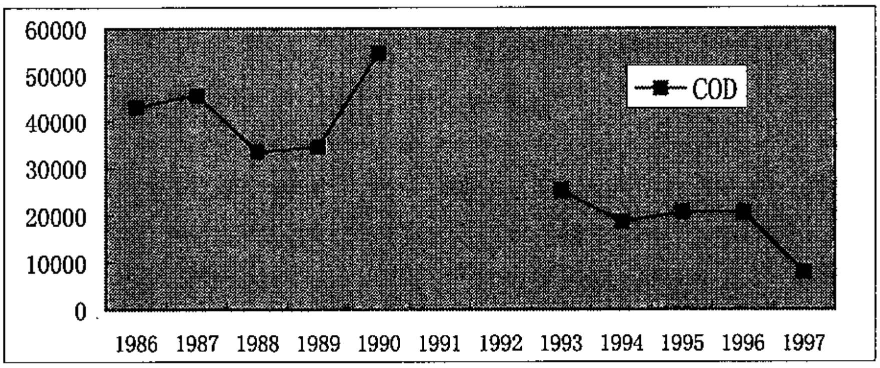
Figure 3- 3 The Industrial Wastewater Discharge conditions in Dalian City, 1986-1996



The main pollutants in the wastewater are volatile phenol and COD. From 1986-1990, the total annual COD discharges raised from 42989 tones to 54802 tones; from 1993 to 1997, the total annual COD discharges decreased from 25140 tones to 7984 tones. That means that water pollution was not under control in the period of 80's, but it has been effective controlled since 90's. Concerning the heavy metal emission of Cr^{6+}, it is continuously decreased since 1981.

The leading pollutants in the urban wastewater are COD, suspended particles, heavy metal, oil species and so on. And the leading pollution sectors are petrochemical industry and chemical industry, whose discharge took up 87% of the total amount of industrial wastewater discharge in 1998. And the most serious polluting areas are Ganjingzi District and Dalian Economic and Technical Development Zone, which contributed to 65% and 23% of the City's total amount of industrial wastewater discharge in 1998.

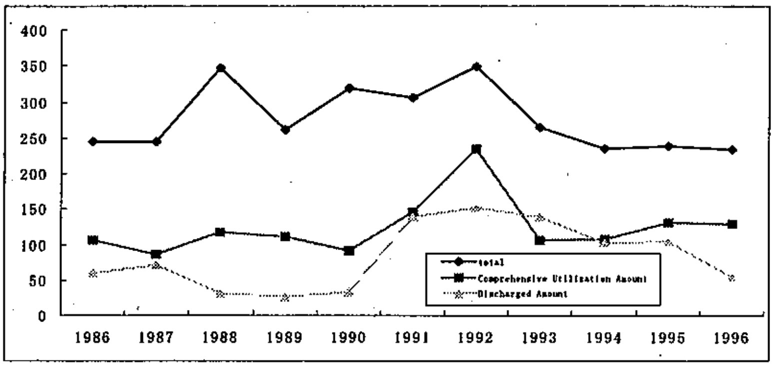
Figure 3- 4 The Emission Trend of COD in Dalian from 1986-1997



3.2.3 Solid Wastes

Solid wasters mainly refer to industrial solid wastes and urban rubbish from living. In 1998, the amount of industrial solid wastes was 25.43 million tons and the total amount of garbage was 11,08 million tons, with a ratio of 2.3: 1 between them. Since 1992, production of industrial solid wastes has assumed a tendency of steady decline. In 1996, it reduced by 16.16 million tons compared with that of 1992.

Figure 3-5 Changes of sold wastes production of Dalian City



3.3 Environmental Quality of Dalian City

On the whole, Dalian enjoys a fairly good environmental quality. Since the implementation of the system of quantitative examination for integrated urban environmental treatment in China, Dalian has secured a leading position among all the participating cities, and was named a national model City on environmental protection in 1997.

3.3.1. Urban Water Environmental Quality and Its Changes

- Environmental Quality of Offshore Waters:

Primary contaminants causing water environmental pollution in Dalian's near-shore areas are inorganic nitrogen, phosphate, oil species, suspended particles and COD. According to the 1998 monitoring results, all indicators, except inorganic nitrogen, met the national standard for function areas. Since 1980, the main trend of the seawater quality changes in Dalian Bay has showed a dramatic decrease of the index of oil species contamination. 1997 saw a sharp plummet with almost 100% less than that in 1980. COD contamination indicator has been improved generally; but the index of inorganic nitrogen pollution has shot up, with 159.4% more in 1997 than in 1980; and phosphate pollution indicator has been climbing steadily since 1992. To conclude, the main pollutants of the seawater environmental pollution in Dalian City are nitrogen and phosphorus.

Table 3- 3 Seawater Quality and Its Changes in Dalian Bay

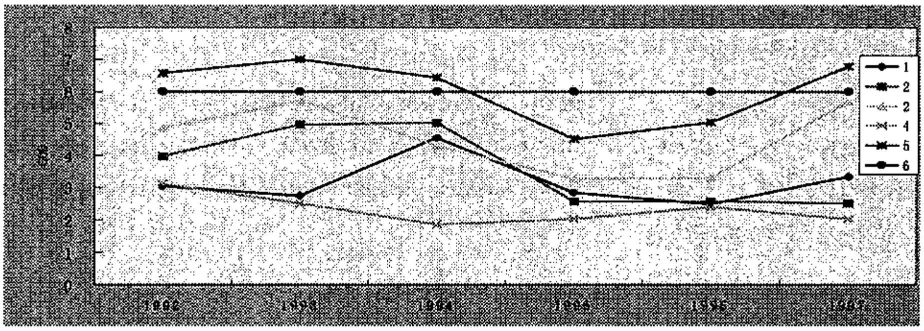
Year	Inorganic Nitrogen	Oil Species	COD	Phosphate
1980	0.424	0.080	1.67	-
1985	0.202	0.053	1.76	0.004
1989	0.857	0.081	1.14	0.0175
1992	0.689	0.076	0.82	0.0099
1993	0.801	0.087	1.13	0.0108
1994	0.920	0.101	1.13	0.0097
1995	0.724	0.075	0.081	0.0160
1996	1.100	0.055	1.09	0.0129
1997	0.673	0.043	1.69	0.0196

Source: Environmental Yearbook of China;Dalian Yearbook.

- Surface Water Quality:

The prime pollutants of Dalian City's surface water are: COD, suspended particles, ammonia, nitrogen and oil species. Monitoring results since 1992 have shown that water quality of these rivers, except Dalian's Shahe River, can approximately meet the national standard type III for surface water environmental quality. In general, surface water environmental quality is, in the mainly, unchanged as in 1992.

Figure 3- 6 Changes of COD Concentration of the Main rivers in Dalian



Note: 1. Data are taken from *Dalian's Yearbook;* 2. curves 1--5 are for Biliu River;Zhuanghe River, Dengsha River respectively and curve 6 is the standard for the surface water quality type III

3.3.2.Urban Air Environmental Quality and Its Changes

In 1998, with the only exception of natural dust-fall indicators of the urban atmospheric environmental quality and its changes of Dalian City, met the national standard of air quality Grade II, indicating a positive air environmental quality. For changes in the atmospheric environmental quality of Dalian City since 1986, please refer to table 3-5. Monitoring indexes indicate that Dalian's air quality is developing healthily in all aspects, with every atmospheric pollution indicator decreasing annually.

Table 3- 5 Urban Air Quality and Its Changes, 1986-1996

	SO2 (mg/m³)	NOx (mg/m³)	TSP (mg/m³)	CO (mg/m³)	Natural dustfall (tone/km².month)
Standard of II Air Quality	**0.060**	**0.050**	**0.200**	**4.0**	**8.0**
1986	0.060	0.060	0.420	2.04	29.0
1987	0.060	0.060	0.430	2.29	27.6
1988	0.060	0.060	0.440	3.30	24.7
1989	0.054	0.065	0.400	2.62	23.7
1990	0.038	0.071	0.330	2.75	23.4
1991	0.038	0.070	0.328	2.74	22.0
1992	0.082	0.104	0.135	1.84	23.2
1993	0.071	0.095	0.142	2.04	24.8
1994	0.070	0.100	0.192	2.17	21.2
1995	0.060	0.100	0.288	1.98	18.0
1996	0.060	0.070	0.222	1.87	20.0
1997	0.058	0.056	0.151	1.92	18.6
1998	0.058	0.047	0.166	1.89	14.7

Source: Dalian Yearbook; The Ninth Five—year Plan of Dalians Environmental Protection and Study of the Long-term Plan for 2010, Dalian Environmental Science Design Institute, 1995.

The first over limit rate of natural dustfall was 75.8%. The maximum monthly mean was 110.8ton/km² (1993) with 12.9 times over the standard instituted by Liaoning Province, and the maximum monthly mean was 24.8 ton/km²(1993) with 2.1 times over the standard. In 1996, the first maximum monthly value was 20.0 ton/km² with 1.5 times over the standard instituted by Liaoning Province. Although these estimates still exceeded the Environmental standard, it is going to decrease since 1990s.

3.3.3. Urban Noise Pollution and Its Changes

In 1998, the average equivalent noise grade of Dalian City is 56.4 dB, almost unchanged over the previous year. In the urban function areas, the weighted mean value is 56.5 dB during the day and 47.4 dB at night. The weighted mean value for urban traffic noise in the city section is 69.9 dB. The noise index for each function area approximates to the national standard, with only a few areas exceeding it slightly. The coverage of areas that have met the standards is 61.8% citywide.

3.3.4. Urban Ecological Environment

Dalian's urban ecological environment is also improving gradually. In 1998, the city had a total green area of more than 6.00 millions square meters, with an annual increase of more than 1 millions square meters. It achieved a green land coverage rate of 39.30% and provided a green area of 7.2 square meters per capita, which represent respectively an increase of 5.5% and 3 square meters per capita over 1992. Dalian's urban green land coverage rate exceeds the national average rate by 14.6 percentage points. Improvement of the urban ecological environment has created a good image of an ecological city of Dalian, which provides a boost to Dalian's tourism and economy.

3.4. Major Environmental Problems of Dalian

3.4.1 Recognition and Evaluation of Major Environmental Problems

According to Dalian`s social and economical development and also the emission of various pollutants and the development of the city's environmental quality changes, we can obtain an overall evaluation of the major existing and insidious problems facing Dalian:

- coal and smoke air pollution, including pollution from industrial sources as well as from living sources;
- urban sewage treatment, the effective treatment of which is the fundamental way out for the improvement of the urban surface water environmental quality;
- the industrial pollution control, which involves air and water treatment;
- ocean environmental pollution, especially the nitrogen, phosphorus pollution of offshore seawaters;
- traffic-induced environment pollution, including control of waste gas pollution from motor vehicle and of traffic noise;
- environmental protection in serious polluted areas;
- pollution from township enterprises.

3.4.2. Major Urban Environment Problems

- Industrial Pollution Control

From the foregoing analysis of the emission of air and water pollutants, we can conclude that emissions of industrial waste gas and wastewater are the main causes for urban water and air pollution in Dalian. In 1996, their emission contributed to 83.2% and 73.1% of the total emission of waste gas and wastewater of the city respectively.

Through sustained efforts, the proportion in total emission of industrial wastewater and waste gas is also reducing year by year. However, the total emission of all the pollutants is still high, imposing a great pressure on urban environment. In such a case, control of industrial pollution, through reducing the emission of industrial pollutants, is the starting-point for improving the urban water and air quality of Dalian.

- Air Pollution of Coal Consumption

They include coal and smoke air pollution caused by both industrial and living elements. Coal is the chief fuel for Dalian City, and such an energy consumption pattern will likely remain long. With the social and economic development and the rising of people's living standards, consumption of fuel coal is expected to increase year by year. The emission of smoke dust and sulfur dioxide is imposing a lasting pressure on the urban air environment. Recent years has seen a gradual decline of the indicators for such leading air pollutants as sulfur dioxide, suspended particles and natural dust fall. However, compared with Grade II of the standards on the national atmospheric environmental pollution, occurrences of exceeding the standard happen now and then, indicating the seriousness of the pollution situation.

- Treatment of Urban Sewage and Urban Garbage

As the majority of the urban sewage from living drains into the sea directly through the city's underground sewer system without any treatment, and some even directly drains into the city surface streams, serious pollution of the offshore area and urban surface water occurs. Therefore, both maintenance and improvement of the urban water environment call for a reinforced treatment of the urban sewage. At present, however, Dalian's treatment of urban garbage is still at a low level, just burying it in landfills or simply throwing it away in city dumps. In view of the necessity to improve urban environment quality, the city's treatment level and treatment rate of urban garbage must be raised in the future.

- Ocean Environmental Pollution

As seen from the foregoing analysis, near sea waters of Dalian City are being polluted more and more seriously. At present, contents of nitrogen and phosphorus in Dalian Bay area have doubled over that of 1980. In recent years, red tides have occurred in the sea area near Dalian, which not only further deteriorates seawater quality, but has also creates unfavorable effects for seawater cultivation and tourism.

- Environmental Pollution Caused by Traffic

Due to its rapid development, of Dalian urban transportation is producing a greater impact on the city's environment. Environment problems arisen therefrom mainly appear in two fields. First, it is the heavy pollution of waste gas from motor vehicles. Monitoring results show that Dalian's atmospheric pollution in summer is mainly caused by motor vehicles' exhaust gas. Second: noise pollution from the urban traffic, railway and air transportation is still serious.

- Environmental Pollution of Central Urban Areas

In the urban section, Ganjingzi district is most heavily crowded with industries. In order to achieve Dalian's overall goal of urban development and to improve its urban environmental quality, great efforts must be taken to tackle the pollution in this district.

- Pollution Caused by Township Enterprises

Township enterprises are developing rapidly and are occupying a more and more important part in Dalian's overall industrial economy (see section 2.3.3.). At the same time, their pollution is also becoming more serious, impairing the environmental quality of Dalian's surrounding areas. Seen from a long-term perspective, adequate attention must be oriented to this direction.

4. Responses to Improve Urban Environment in Dalian

4.1 Reponses at the Central Level

Environmental protection policy systems including related regulations, policies and measures at the state level provide highly effective guidance for the environmental protection policy systems at the local level. In fact, all the regulations and policies of the central government on environmental protection play a critical role in the protection of environment and the prevention of pollution. The environmental management system is mainly consisting of three government agencies: legislation and supervision departments, administrative departments and judicial organs. Among all the above institutions, the administrative management of the government is the main force.

4.1.1 Laws and Regulation

At present, China has already established a comparatively complete system of laws and regulations on environmental protection. By the end of 1999, the Chinese government had promulgated 6 environmental laws, 9 resources protection laws, 28 administrative regulations and 70-odd rules and regulations concerning environmental protection enacted by the environmental protection departments. Besides, 361 national standards on environment, 14 industrial standards had also been adopted. In 1997, related clauses on the punishment of those criminal activities violating environmental resources were entered in the Criminal law of China established. There are five levels of environmental ligislation system: (1) The Constitution; (2) Basic Laws on Environment; (3) Special Laws on Environmental Protection; (4) Special Administration Rules, Regulations & Formal Documents on Environmental Protection; (5) Environmental Standard.

4.1.2 Urban Environmental Management Policy

Comprehensive Management and Improvement of Urban Environment is the major urban environmental management policy in China. Comprehensive management and improvement of urban environment aims at reaching the goals of protecting and improving urban environment by means of legality, economy, administration, technique and others under the unified leadership of the city government. It involves at least three parts, prevention and control of urban industrial pollution, construction of urban infrastructure and management of urban environment. Urban environmental issues result from complicated social, economical and natural environmental backgrounds, which results in the qualities of comprehensiveness and complexity of urban environmental management. Therefore, it is by no means a task solely of the urban environmental management departments. Instead, the forces of urban authorities, enterprises and the public must be mobilized to take up their due responsibilities and duties of the task of urban environmental protection. Moreover, as regards the administration system in China, environmental protection organs at the local level are affiliated to the local authorities, hence except the leadership of the State Environmental Protection Administration for their business operations, their work in other aspects is more under the leadership of the local authorities. Facts have proved that this policy, since coming into practice, has brought about a great advance in the urban environmental protection of China. Quantitative Assessment of Comprehensive Management and Improvement of Urban Environment is the practical measure to promote this policy.

4.1.3 Establishment of Model Cities on Environmental Protection

Based on the policies of the comprehensive management and improvement and the quantitative assessment, the State Environmental Protection Administration launched the activity of establishing model cities on environmental protection nation-wide in 1996. It is in fact another urban environmental protection policy. Its guiding principle is to achieve sustainable development. It aims at bringing the urban environmental quality up to the standards of all the urban functional areas, and causing the cities' authorities to adhere to sustainable development, to perfect urban environment constantly, and to build ecotype cities while maintaining high economic growth rates. To do this, the State Environmental Protection Administration studied and setup assessment criteria for the model cities on environmental protection, which involves urban socio-economy, infrastructure construction, environmental quality and management and others. Because of its strict criteria, the designation of the model cities on environmental protection is regarded as the "Nobel Prize" in the field of urban environmental protection in China. Up to the present, 13 cities including Dalian, Shenzhen, Zhuhai, Xiamen have been designated the title of "model city".

4.2 Responses in Local Level

Governments at all levels and all environmental protection departments in Dalian are greatly concerned with environmental protection and spare a lot of efforts to improve the city's environment quality.

4.2.1 An Complete and Effective Urban Environmental Management System

During 1980s, Dalian established the Environmental Protection Committee, the Environmental Protection Propaganda and Education Center, the Environmental Monitoring Team and other Environmental Protection institutions. Meanwhile, a complete network of Environmental Protection Bureaus and Environmental Monitoring Stations was established throughout all the counties and districts of the city. Functional departments for environmental protection have grown from under 100 staff at the beginning to nearly 1000 at present, forming an effective reinforcement for environmental protection implementation.

In the 1970s when Dalian's environmental protection just started, only incomplete environmental management policies and regulations existed. Since 1980s, Dalian has been working hard for the establishment of systematic local environmental management policies and regulations. In accordance with the national environmental protection laws and regulations, in view of the main tasks confronting local environment protection and in combination with the characteristics of local environmental protection, a series of local environment protection policies and regulations has been established (see Table 4-1). By 1995, a system of urban environment protection laws and regulations of Dalian City had been near completion, providing laws and regulations biding urban environmental protection practice.

4.2.2 Giving Priority to Industrial Pollution Control, Adjusting Industrial Development Strategy

Realizing the characteristic that industrial pollution sources are the major pollution sources, Dalian City has focused its treatment on them. Meanwhile it also makes corresponding adjustment of the local industrial development policies in order to reduce emission of industrial pollutants.

- Focusing on Treatment of Industrial Pollution Sources

In the early 1980s, Dalian finished its investigation of industrial pollution sources, and discovered the major polluting environment, industries and enterprises (see section 3.1). Based on such a foundation and in accordance with related laws and regulations of the central and local governments, Dalian adopted strict measures for supervision and treatment of industrial pollution. Strengthen the construction of pollution control facilities to improve the capability of treatment for industrial exhaust gas and wastewater. Increase investments in administration of industrial pollution, which will enable the municipal government, enterprises and the environmental protection departments to take joint efforts to strengthen pollution control in those major polluting enterprises. The increased investment can also enable them to improve their poor manufacturing technology, to lower the consumption of energy and materials and to establish and perfect facilities for industrial pollution treatment. Restrain the development of those pollution-intensive industries. Enforce the policy of "specifying the deadline for pollution treatment", At the same time, control the emergence of new pollution sources, through the enforcement of EIA to newly started enterprises.

- Adjustment of Industrial Developing Policies

Because of historical reasons, the problem of industrial pollution in Dalian is directly related to the industrial pattern and distribution. As far as industrial pattern is concerned, heavy industries such as metallurgy, chemicals, petrochemicals and cement take a great proportion in the national economy. At the same time, the fact that the industries mainly lie in the downtown and near-suburb area has also contributed much to the negative effects of industrial pollution on urban environment. To deal with these problems, the municipal government of Dalian lays down the following policies:

- Adjust the Industrial Structure

The tertiary industries such as high technology, finance, tourism, harbor and trade will be given priority to, while the proportion of secondary industry should be reduced. These practices have already achieved positive results that the changing industrial pattern has positively effected environmental protection.

- Adjust the Industrial Locations

Those enterprises of heavy pollution will be removed out of the downtown area. Together with the removal, they would be impelled to adjust the product mix, improve production technology, establish facilities for pollution treatment and reduce discharge of waste. Till the end of 1998, the municipal authority listed 115 enterprises that should be removed. The removal is to be finished in 12 batches before 2000. So far, 73 enterprises have been removed and their former residences have been developed, which enhances both environmental and economical benefits. For example, since its removal, Dalian Brewery Company has adjusted its product mix and improved its technical renovation. It established facilities for sewage treatment, which decreased the amount of wastewater and enabled the discharged wastewater to meet the environmental standards. On the other hand, the outputs of beer have increased. Therefore, the company has accomplished both financial and environmental success.

4.2.3 Implementing Comprehensive Urban Environmental Treatment Policy

Another important measure adopted by Dalian in its effort to improve urban environment is to strengthen the comprehensive treatment of the environment, with its focus on improvement of urban ecological environment. Dalian comprehensive urban environmental treatment includes:

- Strengthening the Construction of Urban Environmental Infrastructure

In recent years, more than half of the key projects carried out by the Dalian municipality has been environmental protection projects. In 1994, they invested in infrastructure 337 million RMB, which rose to 154,2 million by 1998. In 1998, urban garbage process rate was 88.2%, collective urban heating rate reached 44% and gas use rate was about 96%.

- Focused on the Comprehensive Treatment of Atmospheric Environment

According to its own characteristics, Dalian approaches its environmental pollution by holding on to the most influential problem — air pollution. It takes a series of comprehensive measures to curb the air pollution, stop the trend of the worsening air quality. These measures include: Imposing Strict Control on the Use of Small & Medium-sized Boilers, Reducing Smoke Dust Emission, Practicing Central Heating Services, Practice Concentrated Control of Air Pollution, move Some Enterprises from the Former Locations, Strengthen the Treatment of the Waste Gas from Motor Vehicles, Improvement of Urban Ecological Environment.

4.2.4 Intensify Urban Environmental Protection

To improve its environmental quality, Dalian city has invested a huge sum of money in industrial pollution management, urban infrastructure improvement and urban ecological environmental reform. Dalian`s input in environmental protection increases year after year and is becoming more and more intense. The input of environmental protection is mainly financed through the enterprises themselves, government subsidies, returned sewage drainage fee, bank loans and foreign capital.

Table 4- 1 The Investment of Industrial Pollution Control in Dalian

Year	Investment(10000yuan)
1990	8197
1991	10940
1992	7000
1993	5446
1994	3000
1995	6005
1996	7878
Total	**48465.7**

Source: Chinese Environmental Yearbook.

4.2.5 Establish Tentative Integrated-Decision-Making Mechanism for Environment Protection

Dalian Municipal Government pays great attention to environmental protection, which has quickened the establishment and perfection of the integrated decision-making mechanism for environment protection, which further makes the urban environmental protection permeate through every side of the society and economy.

4.2.6 Active Participation in International Cooperation and Exchange

Dalian also places great emphasis on international cooperation and exchange. In this regard, the first main measure is going out to get up-to-date knowledge, learn their experience of urban environmental management, especially from the developed countries. The second is to invite them to come here in order to import advanced technique, equipment and ideas of urban management, and also to attract foreign finance to compensate for the lack of environmental finance. The third is to mix with them, to learn their experiences and further develop our urban environmental management mode with our own characteristics according to Dalian`s special features and tasks.

4.2.7 Carry out the Strategy of Urban Development

The main tasks of urban development strategy in Dalian are: controlling population scope, raising population quality, limiting construction scales, promoting environmental quality, restraining industry's scale, promoting its efficiency.

4.2.8 Employment of Suitable Environmental Economic Instruments

Like all other cities in the country, Dalian levies sewage drainage fees on enterprises that drain their wastewater. This encourages the enterprises to treat their pollution. The money thus got is used specially for the treatment of environmental pollution, and will be under the unified management of the government, which will spend it on some key projects according to different emphasis of environmental protection. For key environmental projects, the government will grant them favorable policies in funding and tax paying.

5. The Experiences on Urban Environmental Management of Dalian

5.1 Evaluation on Dalian`s Urban Environmental Management Mode

In general, the evaluation process of a certain environmental management includes the following components: effect of achievement on the environment; analysis of benefit and cost; practicality evaluation; social acceptance and equality; and effect on the economic development.

5.1.1 Environmental Benefit

Dalian`s environmental management mode is remarkably effective in urban environmental improvement. In chapter III, from our discussion of the years of change trend for urban environmental pollution and environmental quality, it is easy for us to draw the following conclusion. Dalian's overall environmental quality has not further deteriorated, despite the rapid and lasting urban economic growth, ever-booming urban population, increasing urbanization process and rising coal energy consumption year after year. This is due to Dalian's efforts to adopt pollution treatments and environmental protection measures (For details, see section 4). At present, Dalian's atmospheric quality is improving, approximately staying at Grade II of the national atmospheric environmental quality. Their index of the atmospheric quality concerning natural dust fall, which is under special control, has declined obviously. The deteriorating trend of water environment has been brought effectively under control. All kinds of water bodies generally meet the standard for the functional area water and some indexes even decrease. In some key treatment areas, the environmental quality shows obvious sigh of improvement. Urban noise and solid waste are more or less got under control, of which noise environment quality is slightly better. The recycling rate of industrial wastes is rising continuously, while its emission is shrinking. Process rate of urban rubbish is also rising. Ecological environment has been greatly improved. Compared with 1970s and 1980s,Dalian city appears much more beautiful than before. To sum up, with the effective mode of urban environmental management, Dalian has geared onto a healthy track with prospect of sustaining development.

5.1.2 Benefit and Cost

In its operation of the urban environmental management mode, Dalian's input in the environmental treatment is increasing which occupies a larger and larger proportion in the national economy. This indicates that the cost for environmental protection is also climbing due to the expansion and accumulation of the volume of pollutant emission. But compared with the acquired environmental results, social effect and economic benefits, such management cost is acceptable. In 1988, gross investment in environmental protection occupied 2.16% of CDP much less than Dalian`s economic growth rate. Therefore, although this management mode may not be the most economic one, it is a cost-effective mode for urban environmental management.

5.1.3 Practicality Evaluation

Based on years of operation of the mode, this kind of environmental management is mainly composed of order giving and controlling, with a combination of other forms of urban environmental management mode. Under China's present social and economic conditions this mode is effective and easy to operate. For other cities where there is an effective government and low economic development level, this mode should also find equally good application.

5.1.4 Social Acceptance and Equality

Dalian`s urban environmental management mode is based on integrated policy-making about environmental issues, and supported by the government, city residents, and other related government departments. Seen from the changes in the enterprises` polluting activities, as main contributors to environmental pollution, the majority of these enterprises have already accepted this environment management mode. For a few enterprises with poor economic benefits, it is difficult for them to meet the requirements of this management mode. But this does not represent the majority of enterprises' interests. As Dalian`s urban environment management mode meets the most people's demands to improve environment quality, it is just, fair and acceptable.

5.1.5 Effects on Economic Development

Dalian`s urban environmental management mode has an important characteristic, that is control of environmental pollution, environmental quality improvement and urban economic development promote one another and develop in a balanced way. Since Dalian put this mode into operation in 1990s, it keeps having high economic growth. Excellent urban environment has attracted huge sum of foreign capital, with an actual annual sum of over 100 million. At present, foreign funded enterprises that are actually in operation have exceeded 6,000 boosting economic development and readjustment of industrial patterns. Along with the improvement of its urban environment, especially its ecological environment, Dalian`s tourism shows a strong developing potential. In 1997, 17205 person/time tourists visited Dalian, in which 205,000 person/time were foreign tourists. Here Dalian earned 200 million dollars.

5.2 Characteristics of Dalian`s Mode for Urban Environmental Management

These characteristics are as follows:

- Implement integrated policy-making mechanism for environmental protection and economic development, obtain good results of both environmental protection and economic development
- Aim at the key problems in the city's environmental pollution, make pollution control strategy, concentrate on management of key pollution sources with different focuses, at different periods and from easy till difficult, meanwhile provide favorable terms to these key problems in terms of finance and policy.
- Emphasize the city's ecological construction, reinforce achievements already made and add value to the invisible value of the environment.
- With order-giving and controlling as main methods supplemented with other environmental management modes.
- Approach to the integrated treatment of urban environment by ways of the city's infrastructure construction and by changing the energy utilization method.
- Curb new polluting sources, and set a deadline for the treatment of old pollution sources.
- Adjust industrial structure and distribution, move polluting enterprises out of the city section, raise their technical and productive level and also their pollution management capacity.
- Divide the city into function areas, emphasize on the treatment of heavily polluted area.
- Keep raising the investment level for urban environmental protection, to improve urban environmental quality.

5.3 Suggestions on Improving Urban Environmental Management Policy

In the document of *Dalian's goal, tasks and measures of environmental protection 1898--2002,* it clearly defines the environmental protection goals for this term of government. The goals are: to comprehensive control of pollution, basic solution of the problem of coal and smoke pollution at the city center, obvious improvement in atmospheric, water and ecological quality, achievement of the environmental quality at the intermediate developed nation's level.

In accordance with Dalian's social and economic development trend as well as is immediate objective of city environmental protection, suggestions for Dalian's urban environmental management is that it should build and improve its urban environmental management policy system. Then it needs to promote clean sanitary production in order to curb pollution from its origin, meanwhile raise the process rate of pollutants and its process level to reduce urban environmental pollution load.

5.3.1 Improve Integrated Decision-Making Mechanism for Urban Environmental Management

Although Dalian has already set up its integrated policy-making mechanism of environmental protection, it is far from perfect. In the future, this mechanism needs to be improved continuously to suit new situation and new demand, and to avoid occurrence of urban environmental problems due to policy-failure.

5.3.2 Build A Market-based Legislation System of Urban Environmental Protection, and Implementing Pollution Control and Environmental Protection by Law

In the past, to a great extent, environmental protection of Dalian City followed an order-giving management mode. In the future, with the increased degree of market-oriented urban economy, administrative orders will have limited effect. Thus, further improvement of urban environmental protection and construction of a system with related laws and regulations is beneficial for promoting the building of the related laws and regulations concerning pollution treatment. It fits the need of the market economy and will provide laws for the treatment of pollution, and in the end it will improve urban environment al quality.

5.3.3 Strengthen Pollution Treatment with Focus on Sewage Treatment

To develop local economy, and to improve urban environmental quality substantially, greater efforts must be taken to sewage treatment. At present, the discharges of industrial water pollutants continuously decrease, but the discharge of sewage water increases very fast in the recent year, and causes some serous environmental problems. It is necessary to raise the volume of treated sewage and rubbish from household and to promote technical level of sewage treatment. For the treatment of industrial and living pollutants, there is a considerable gap between Dalian and Kitakyushu. At present, Dalian's urban sewage treatment rate is only 23%. To really improve the urban quality of water environment, including the water quality of both surface water and near shore seawaters, we must speed up our efforts to build city sewage process factories. Therefore, to increase the treatment of sewage water is one of the priorities for Dalian government in the urban environmental protection in the future.

5.3.4 Build and Promote Market-based Commercial Pollution Treatment Mechanism

In Dalian and also in many developing countries, one of the important obstacles, which disturb the pollution processes, is the money, and the government couldn't afford the high cost for pollution control. But if the pollution treatment or disposal facilities can make money, it will be a good commercial chance for the private and public investors. For a long time, China, in fighting environmental pollution, faces a big problem: the low operation rate of pollution treatment facilities. Its reason lies chiefly in the heavy pressure on the government and enterprises from the money spent to keep the facilities work. So to cater to the requirement of the market economy, our country puts forward the development direction to push pollution treatment to the market and make environmental protection a social business. The commercialization and socialization of pollution treatment can ease government's financial burden and actually realize "polluter pay" principle. Only by doing this, can the pollution treatment plants can get enough financial compensation, so as to maintain the normal operation of the facilities. The solid waste process center at Dalian Economic Development Zone adopts this socialized, commercialized mode for pollution treatment. Facts prove that this mode not only solves the solid waste problem, but also brings good economic results to the company. Hence, this mode should be promoted in Dalian.

5.3.5 Adjust Industrial Structure & Distribution and Promote Cleaner Production

This means to promote cleaner production in the process of environmental treatment in order to control the production and emission of pollution from origin to end. Besides promotion of cleaner production can be combined with industry's structure adjustment and moving of the industry from its former location, in order to help the old pollution sources to change it technique and enhance pollution treatment. Meanwhile, for new projects, use of new cleaner production technique should be encouraged to avoid producing new pollution sources.

5.3.6 To Promote ISO 14000 Environmental Management System

To suit the demand of the growing market, Dalian begins to promote the use of ISO 14000 environmental management system in its environmental protection of industries and enterprises. This can help change the passive work of pollution management and environmental protection toward the active direction. In1999, Dalian adopts the ISO 14000 certification as one of the important tasks. It setup a "Leading Group for the Implementing of ISO14000 certification trial work". Now 6 enterprises have already passed the environmental management system ISO 14000 certification. In the future more efforts will be taken to further promote it.

5.3.7 Promote Regional Environmental Protection

The urban environmental Quality is not only depend on the pollution control and urban ecological construction in the city itself, it is also related to the pollution control and ecological conservation in the around regions, e.g. the natural dust falling and water pollution. Nowadays, although Dalian has paid a lot of attention in the dust control and ecological conservation, the indicator of air quality, natural dust falling, is still above the national standard. The result, in some degree, is due to the lot of constructing sites, which cause secondary pollution, but it is also closely related to the widely regional ecological situations. If there are a lot of ecological and environmental problems in the around areas, e.g. deforestration, soil erosion, and serious water pollution, air and water quality of the central city will be influenced and become worse. It is just because the urban environment is just one part of the whole regional ecosystem. That is why we couldn't focus our urban environmental protection activities just in the city it self, we should pay more attentions to the regional ecological and environmental protection in the further.

5.3.8 Intensify Environmental Education, To Promote Public Participation and Awareness

Dalian has been very active with efforts to educate the public on environmental protection and to encourage the public to join in environmental protection. Dalian City mainly does so by publicizing environmental information to increase the transparency of the work. On May 15, 1998, Dalian took the initial action to become the first city nationwide to announce daily reports on the city's atmospheric quality. This year, it started the city environmental quality forecast. In the future, Dalian will continue to strengthen its education of the public on environmental protection, raise the pubic awareness so that they will participate in this work willingly. Pubic participation can be a valuable help to the concerned government departments, they can supervise and report incident of pollution and bad behaviors that cause damages of environment. In this way, a society with good atmosphere of protecting the environment is being created.

Problems and Solutions of Water Environment and Urban Traffic in Xian City

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1. Introduction

In recent years, China has been undergoing a very fast urbanization, which is characterized by the rapid transformation of population from rural dwellers into urban residents and the accelerated urban expansion. Up to the end of 1996, the residents living in cities have reached 42.1% of the total population in the country (Urban societal and economic survey team, State Statistical Bureau 1998). Along with the rapid urbanization in China, however, many cities have encountered more serious urban problems than before like crowded traffic, tight housing, insufficient water supply, polluted environment and so on, because the construction of urban infrastructure was not able to keep up with the growths of both economy and population (Kang 1998).

Here we will, through a case study of Xian City, examine the conflict between the fast growths of economy and population and the slow urban infrastructure construction, and thus discuss many problems induced by this conflict. We will concentrate on two environmental problems in Xian: One is the water shortage and the deterioration of water environment, and the other is the crowded urban traffic. We will analyze the problems from the aspects like the current status, future prospects and strategies. Furthermore, we will provide some suggestions that shed light on tackling similar environmental problems encountered in many other cities, especially in northern China and other Asian countries.

1.1 Background of Xian City

Xian, an ancient city with an age of at least 3100 years, is located in the central part of China and the capital city of Shaanxi province. In Chinese history, Xian had been the capital for 12 dynasties since 1136 BC, because of its pivotal location and favorable natural conditions (plain terrace land near Weihe River -the largest tributary of Yellow River, temperate climate, and fertile soil growing with dense forest and grassland).

Xian lies on the north of the Qinling Mountain ranges, south of the Loess Plateau, west of Linghe River and Bayuan Highland, and east of Taibaishan, the highest peak of the Qinling Mountain ranges. Its latitude ranges from 33°39' to 34°45' N, and longitude ranges between 107°40' and 109°49'E.

Xian has jurisdiction over 7 sub-administrative districts (Xincheng, Beilin, Lianhu, Yanta, Weiyang, Baqiao, Yanliang) and 6 suburb counties (Lintong, Chang'an, Gaoling, Lantian, Zhouzhi and Hu). The total acreage of Xian is about 9983 km^2.

From 1990 to 1997, Xian had experienced unprecedented economic and social developments. Up to the end of 1996, the built up area in city proper takes 148km^2 and the registered population has reached 3.033 million. Among the population 2.206 million people (taking about 72.7% from the total) are non-agricultural urban residents. Inaddition, the transient population coming from surrounding rural areas and other places, the average population has reached up to more than 3.6 million. Meanwhile, population density in city proper has increased from 2548 persons/km^2 in 1990 to 2845 persons/km^2 in 1996 (Xian Statistical Bureau 1998). In 1996, Xian's Gross Domestic Product (GDP) reached 32.259 billion RMB *yuan* (approximately 3.887 billion US dollars), which was an increase by 12.3% over that of 1995 according to a fixed calibration, and more than a doubled number compared with 1990 (Xian Statistical Bureau 1998).

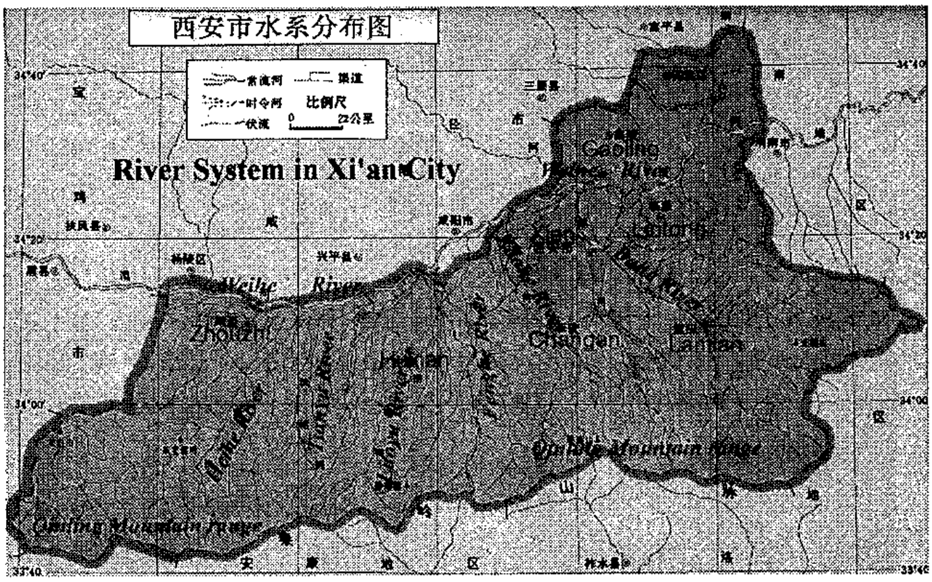
2. Water Environment: Current Status, Future Prospects and Strategy

2.1 Status of water resources

2.1.1 Outline of water resources

The water resources of Xian City are made up of precipitation, surface flow and ground water. The system of surface flow is composed of 54 rivers, in which Weihe River system, the largest tributary of Yellow River system makes the most part (Fig. 1).

Fig. 1 River system in Xian City



The large rivers include Weihe River and its tributaries such as Bahe River, Fenghe River and Heihe River, and so on. Most of them originate from the Qinling Mountain range or surrounding hills, and flow through the city from south to north till emptying into Weihe River.

The average runoff amounts to 2.487×10^9 $m^3 \cdot a^{-1}$, including rivers passing through Xian (Weihe River, Jinghe River) and rivers within Xian (Heihe River, Fenghe River, Bahe River). The ground water comes mainly from two sources: One is crevice water from the bedrock of Qinling Mountain ranges and the other pole water from the sediments of plain areas. The total groundwater resources of Xian amounts to 1.695×10^9 $m^3 \cdot a^{-1}$.

Thus, the total water resources of Xian City is 3.146×10^9 $m^3 \cdot a^{-1}$, excluding the repeating amount (1.036×10^9 $m^3 \cdot a^{-1}$) induced by the interchange and replacement between surface water and ground water. Till 1994, the average water possession per capita was 492 m^3, accounting for only a little more than one fifth of the average of the country (2425 m^3 per capita).

2.1.2 Present status of water resources

The statistics shows that in 1995 the amount of guaranteed surface water was 1.1×10^9 $m^3 \cdot a^{-1}$, the exploitable ground water was 1.38×10^9 $m^3 \cdot a^{-1}$, and the total of two was 2.48×10^9 $m^3 \cdot a^{-1}$. Moreover, some of wastewater could be reused.

There are 11 reservoirs in and around the city with a whole water storage of 0.157×10^9 m^3 and 699 ponds with the reserving capacity of 7.06×10^6 m^3. Moreover, there are 662 fixed water pumping stations, 50.866×10^3 wells and 10.81×10^3 km water channel. The actual yearly amount of water use in 1995 was 1.789×10^9 m^3, of which the surface water was $0.707\times10^9 m^3$, ground water $1.082\times10^9 m^3$. The amount of residential and industrial uses in city proper was $0.359\times10^9 m^3$, the amount of irrigation water and domestic uses by people and livestock in the countryside was $1.430\times10^9 m^3$.

In 1997, there were 7 water supply plants in city belts with a supply capacity of 1.4022×10^6 $m^3 \cdot d^{-1}$, of which the ground water took $742\times10^3 m^3 \cdot d^{-1}$, accounting for 52.9%, and the surface water 660×10^3 $m^3 \cdot d^{-1}$, accounting for 47.1%. The actual total yearly water supply amounted to 373.65×10^6 m^3, being equal to 1.024×10^6 m^3 d^{-1}. Meanwhile, the demand amount of industrial water was $280\times10^6 m^3$, the demand amount of domestic water was 230×10^6 m^3, then the deficit of water supply was 136.35×10^6 m^3, being equal to the daily shortage amount of 373.6×10^3 m^3.

2.1.3 Drinking water sources of the city

In Xian City, the drinking water sources distribute mainly around the city proper. Although the pumping modes were different, the supply for ground water and surface water is both from rivers. The main sources of ground water are Bahe River, Fenghe River, Weihe River and Shahe River. The main sources of surface water are Chanhe River and Qujiang Lake. The latter is the converging station -

through water diversion works from 1996 on- for five rivers along the north piedmont line of Qinling Mountain range such as Shibianyu River, Shitouhe River, Heihe River, and so on. Besides, some other small amount of water is pumped out from the wells at Xiguan in west part of city proper, Chanhe River basin and Duan Village.

2.1.4 Problems on utilization of water resources

- Shortage of water supply

In 1995, the amount of water supply accounted for only 62.6% of the water demand in Xian. This is mainly due to the natural conditions. The average amount of water resources per capita in Xian accounted for only one fifth of the average amount in the country (1995), showing lack of absolute amount of water resources. Meanwhile, the distribution of water resources is uneven spatially and temporally: Mountainous areas are richer than plain areas, and the South is richer than the North. The fluctuation of water resources both between years and within a year is great, which in some extent adds difficulties to the availability of water resources.

- Deterioration of water environment

The deterioration of water environment is represented by the severe water pollution. In 1994, about $284.46\times10^6 m^3$ wastewater was discharged into the rivers. Plus the domestic sewage, about $780\times10^3 m^3$ wastewater is discharged daily. Only no more than 35% of the wastewater is treated by wastewater treatment systems before it's going into various rivers or lakes. At the same time, solid waste residue and garbage were heaped at will, which resulted in the indirect pollution of ground water through rain-wash. On the other hand, the environment in riverhead areas got damaged because of random cultivation, denudation and other irrational land uses, so both the quantity and the quality of water resources were decreased severely.

- Low efficiency on water resources utilization

The efficiency of water resources utilization in Xian is quite low. First, the amount of water used per unit industrial output value is large, which is due to the backward technology and aging equipment. Second, the recycled use of wastewater in industrial sectors is small. Third, there is no integrated management on water resources. And fourth, the price of water resources is too low to reflect the real cost and value of water resources. In addition, people have litter awareness of water resources economics.

- Severe over-pumping of ground water

Either industrial or domestic water utilization depends mainly on extracting ground water, so the demand is large while the replenishment is limited. At the same time, more and more institutions and enterprises get water supply by pumping water out from their own wells, which also causes the severe overtaking of ground water and aggravates the unbalance between extraction and replenishment of ground water. Long term over-pumping has resulted in not only water shortage, but also subsidence of ground and speed-up of activity of cracks under ground.

2.2 Status of water environment pollution

2.2.1 Surface water pollution

❑ Assessment on the surface water quality

From the 1950s, the water quality of Xian's rivers has been deteriorated due largely to "three wastes" pollution. After 1980, though with improved management on water resources, the non-attainment of water standard was still serious, due to the time-lag of the water pollution. Since the implementation of environmental protection policies, seven indices (i.e., volatile phenol, cyanide, mercury, arsenic, hexad chrome, cadmium, and lead) had been monitored first on Weihe River, Bahe River, Zaohe River, Juehe River, Dahuanhe River, Xingqing Lake and Tuanjiexi waste water reservoir.

Table 1 Comprehensive assessment on pollution in major rivers of Xian in 1996 and 1997

River	Weihe		Chanhe		Bahe		Fenghe		Yuhe		Zaohe		Total	
	96	97	96	97	96	97	96	97	96	97	96	97	96	97
TSP	3.5	2.52	1.41	0.74	1.12	0.67	0.81	0.59	0.84	0.45	2.20	1.77	9.89	6.74
Total hardness	0.55	0.57	0.48	0.56	0.40	0.49	0.41	0.47	0.58	0.58	0.56	0.53	2.98	3.20
Permanganate index	7.93	7.37	3.49	3.83	1.38	1.48	4.13	5.84	7.73	3.07	5.82	5.94	30.48	27.53
BOD	3.79	5.63	2.65	3.69	1.01	1.28	3.73	3.23	5.26	2.69	4.61	4.37	21.04	20.89
Non-ionic index	27.12	38.55	6.12	13.24	0.26	1.59	1.40	2.90	5.61	0.70	202.5	12.16	243.0	69.14
NO_2-N	0.62	1.12	1.03	1.44	0.33	0.38	0.21	0.42	0.22	0.56	0.56	0.60	2.97	4.52
NO_3-N	0.04	0.04	0.09	0.07	0.08	0.07	0.03	0.04	0.05	0.05	0.05	0.04	0.34	0.31
Volatile phenol	6.89	8.07	2.58	3.28	1.28	1.47	2.10	6.17	3.67	1.62	6.78	12.12	23.57	32.73
Cyanide	0.06	0.04	0.74	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.43	0.27	1.26	0.37
Total As	0.44	0.15	0.14	0.09	0.06	0.06	0.09	0.11	0.07	0.09	0.11	0.07	0.91	0.57
Total Hg	0.64	0.59	0.48	0.29	0.26	0.49	0.47	0.39	0.52	0.27	0.33	0.27	2.94	2.07
Cr^{6+}	1.30	1.20	0.59	0.86	0.54	0.77	0.53	0.71	0.63	0.44	0.94	1.29	4.53	5.23
Total Pb	1.21	0.30	0.89	0.76	1.13	0.51	1.16	0.27	0.73	0.12	1.41	0.34	6.53	2.3
Total Cd	0.18	0.11	0.11	0.11	0.36	0.10	0.20	0.10	0.12	0.10	2.78	0.10	3.75	0.62
Mineral oil	63.32	79.28	63.46	120.3	25.82	34.22	40.56	33.01	45.29	18.60	17.86	26.57	256.3	312.0
Comprehensive pollution index	117.6	145.5	84.26	149.3	34.26	43.36	55.84	54.26	71.32	29.35	246.9	66.43	610.5	488.2
Pollution load	29.81		30.57		8.88		11.11		6.01		13.61			
Order (1997)	2		1		5		4		6		3			

Source: "Reports on Xian's environmental quality, 1997"

It showed volatile phenol was the most severe pollutant, hexad chrome the second especially on Zaohe River and Tuanjiexi reservoir. Monitoring data showed the concentration of volatile phenol exceeded by 10 times and hexad chrome by 2.2 times higher than the standards. Also deleterious agents such as cadmium and lead were detected. For example, the fish from the reservoir had odd smell and could not be eaten. Aberration and mutation had been found in the fish.The main pollutants of 10 rivers ordered in 1996 were petroleum, permanganate index, ammonia, volatile phenol, and biochemical oxygen demand (Table 1). In 1997 the order changed to petroleum, volatile phenol, non-ion ammonia, permanganate index, and Biochemical Oxygen Demand (BOD). The pollution style was still organic. Heavy metal pollution was slight, but the hexad chrome pollution was comparatively prevailing. The river sections that pollution index was large than 1 accounted for 34.6% of the total assessed ones. The six main rivers in Xian in terms of comprehensive pollution indices were as follows, Chanhe River, Weihe River, Zaohe River, Fenghe River, Bahe River, Yuhe River.

- Pollution changes along river sections

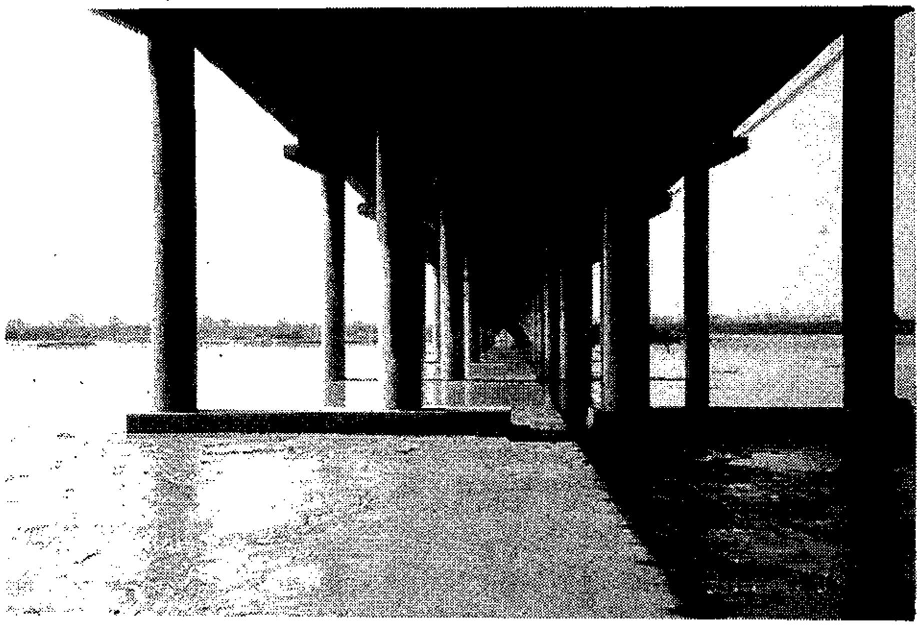
The pollution of the upper reaches of Chanhe River, Bahe River, Zaohe River, Fenghe River was comparatively slight. The comprehensive section pollution index is under 35 at large; the non-attainment index was mainly petroleum index, and other indexes were comparatively slight. When these rivers flow to the Xian city, the section comprehensive pollution indexes increased by large extent and the water quality deteriorated severely because the villages and towns as well as city itself along the rivers discharged much sewage directly into the rivers.

When Weihe River flows from Xianyang City to the section of Xianyangtieqiao (Xianyang iron bridge, coming soon into Xian City), the pollution index reached 153.57. There were eight indexes exceeding the grade III and the water quality was inferior to the grade V according to *National surface water environmental quality standards.* After Weihe River flows by the city, the water quality in all sections deteriorated much more for the wastewater from dykes and streams converged into it (Fig. 2). The pollution index of the lower reaches of Weihe River descended somewhat as the dilution of Bahe River that empties into it.

- Pollution changes in recent years

From the Table 1 above it can be seen that the pollution of Weihe River, Chanhe River, Bahe River in 1997 became more serious than that in 1996 and the comprehensive pollution index increased by 28.0, 65.0 and 9.1 respectively. The pollution load sharing indexes increased largely in petroleum and non-ion ammonia. Although the water quality of Zaohe River and Juehe River was inferior to grade V, the pollution was abated apparently and the comprehensive pollution index descended greatly. Both of two rivers showed the descent of the petroleum and non-ion ammonia pollution. It was because many small enterprises were closed up or phased off by regulations to reduce the discharge. The pollution of Fenghe River did not change much. Among all the sections, the largest augment of pollution index was in the section where Xinhe River flows into Weihe River because of much volatile phenol; the largest descent was in Yianqiumen of Zaohe River because the sharp decrease of non-ion ammonia pollution. In general, the main indices were similar in degree in these two years, but the petroleum and volatile phenol pollution increased, and the non-ion ammonia pollution decreased largely, still other indexes changed in small scale.

Fig. 2 Pollution in Weihe River



2.2.2 Ground water quality

- Features of underground water

The ground water can be distinguished as underground water (the shallow ground water) and confined groundwater (the deep ground water).

The mineralization rate and chemical background value of the underground water in Xian is 390-810 $mg \cdot l^{-1}$, belonging to low mineralization water. But there are apparent zonal pollution haloes around the city proper and the sewage irrigation area in north suburb. This means that the water quality from the good in the south -low mineralized water under 1000 $mg \cdot l^{-1}$ attaining the national standard for domestic water-, becomes bad in the city proper and the north -sewage irrigation zone- with high mineralized water even over 2000 $mg \cdot l^{-1}$. The zone with the high mineralized water over 1000 $mg \cdot l^{-1}$, distributes from the city proper to Youjia Village in north suburb and to Sanqiao Town in northwest with an area of 159 km^2, which is 17 km^2 larger than the previous year. In 1997 the highest mineralization rate detected was 2392 $mg \cdot l^{-1}$, appearing near Shuyuanmen, a central downtown area in the city proper.

The background value of gross hardness of underground water in Xian is 192-333 $mg \cdot l^{-1}$, belonging to the grade of drinking water. In 1997, the water with the gross hardness over 450 $mg \cdot l^{-}$

^{1} distributed at the zone around the center of the city proper, southeast to Dayanta (Wild Goose Pagoda), north to Youjia Village, northwest to Sanqiao Town, and east to Shilipu Town. The acreage of this zone was 243.7 km^2, 3.7 km^2 larger than that in 1996. The highest value of gross hardness reached 882 $mg \cdot l^{-1}$.

The background value of nitric acid in underground water is 0.56-8.58 $mg \cdot l^{-1}$, belonging to the grade of drinking water. Xian has been a capital for China in the ancient dynasties and for provincial government ever since, and adopted sewage irrigation in the recent tens of years, thus the nitric acid pollution is severe. Nearby Caotan Farm along the south bank of Weihe River and at Jianjia Village in west suburb, the nitrous acid pollution in underground water exceeds standards severely because of the abuse of the organic and chemical fertilizers in recent years. In 1997, the highest value was 4.18 $mg \cdot l^{-1}$, exceeding standards by 64 times.

The background value of chloride in underground water is 10.52-32.09 $mg \cdot l^{-1}$, belonging to the grade of good drinking water. In 1997, the area where the value did not attain the standards -higher than 250 $mg \cdot l^{-1}$- enlarged to 68.7 km^2, being 53.7 km^2 larger than previous year and mainly distributing at the urban areas -from Jianjia Village in west suburb to Youjia Village in north suburb.

The background value of hexad chrome in underground water is 0-0.17 $mg \cdot l^{-1}$. Because of the industrial "three wastes" pollution, parts of the content of hexad chrome increased apparently. In 1997, the pollution area with the content over the standards rose to 27.5 km^2. The background value of florin in underground water is 0.24–0.48 $mg \cdot l^{-1}$, belonging to the low florin water. In 1997, the average content of florin in underground water was 0.47 $mg \cdot l^{-1}$, and the area where the content was higher than 1.0 $mg \cdot l^{-1}$ rose to 25 km^2. The highest content was 1.7 $mg \cdot l^{-1}$.

- Features of confined ground water

The confined ground water in Xian is embedded deeply (70 to 300 m below the ground) and on its top there is an aquiclude (water isolation stratum) containing powder clay, so the man-made pollution is slight. The regional pollution is not apparent and the water quality is good at large. But in some segments, because of the water leakage during the course of digging well, the upper underground water pollution affected the lower confined ground water quality.

Some of the contents of florin and arsenic in confined ground water have been high for many years with the non-attainment area 53.1 km^2, where there is a gradient that the deeper into the underground, the heavier with contents load. This indicates that the pollution of this kind is mainly caused by the original environmental conditions such as rupture of rock strata, while the man-made pollution is the subordinate.

- Monitoring result of ground water quality

The survey of ground water in 1997 showed that except for the average content, non-attainment rate and area of florin ion which were lower than that in 1996, all the other chemical contents were higher than that in 1996. The average degree of mineralization, nitric acid, nitrous acid, hexad chrome in confined ground water were all higher than that in 1996, and the other chemical contents lower than that in 1996 (Table 2, Table 3).

Table 2 Acreage of ground water pollution (km^2)

Year	Underground water						Confined ground water	
	Mineralization	Total hardness	NO_3^-	Chloride	Fluorine	Cr^{6+}	Fluorine	Cr^{6+}
1996	142	240	78	15	119	24	101	24
1997	159	243.7	119.3	68.7	25	27.5	53.1	15.6

Source: "Reports on Xian's environmental quality, 1997"

Table 3 Result of water pollution in both underground and confined ground

Item	Year	Number of monitoring	Number of non-attainment	Non-attainment rate (%)	Range of content ($mg \cdot l^{-1}$)	Mean ($mg \cdot l^{-1}$)
Mineralization	1996	60	7	11.67	184.0 - 2724.0	628.7
	1997	60	9	15.00	188.0 - 2392.0	622.7
Total hardness	1996	60	17	28.33	35.00 - 1040.8	316.4
	1997	60	16	26.67	15.00 - 888.30	327.81
Chloride	1996	60	2	3.33	5.7 - 356.2	72.1
	1997	60	4	6.67	5.3 - 430.8	76.7
SO_4^{-2}	1996	60	2	3.33	11.0 - 456.3	105.8
	1997	60	5	8.33	13.4 - 511.5	106.0
NO_3^-	1996	60	10	16.69	0.1 - 880.0	45.0
	1997	60	11	18.33	< 2.50 - 808.5	50.3
NO_2^-	1996	60	7	11.67	< 0.001 - 0.300	0.032
	1997	60	12	20.00	< 0.003 - 4.180	0.788
Fluorine	1996	60	14	23.33	0.15 - 2.45	0.65
	1997	60	6	10.00	0.14 - 1.82	0.52
Cr^{6+}	1996	60	5	8.33	< 0.012 - 1.200	0.035
	1997	60	6	10.00	< 0.002 - 0.580	0.027
As	1996	60	0	0	< 0.002 - 0.041	0.0037
	1997	60	0	0	< 0.002 - 0.044	0.0036
Phenol	1996	60	0	0	< 0.001 - 0.001	< 0.001
	1997	60	1	1.67	< 0.001 - 0.010	< 0.001

Source: "Reports on Xian's environmental quality, 1997"

Eight indices were chosen for the ground water quality assessment -the degree of mineralization, gross hardness, nitric acid, nitrous acid, cyanide, vitriol, florin, and hexad chrome-, all of which have a great effect on the quality of ground water according to the conditions of ground water monitored in Xian. Adopting the standards of GB/T14848-93 *Ground Water Quality Standards* as in Table 4, the outcome of the evaluation is as follows:

Table 4 Classification of the ground water quality

Indicator \ Grade	I	II	III	IV	V
Total hardness	≤150	≤300	≤450	≤550	>550
Mineralization	≤300	≤500	≤1000	≤2000	>2000
Chloride	≤50	≤150	≤250	≤350	>350
SO_4^{-2}	≤50	≤150	≤250	≤350	>350
NO_2^-	≤0.0032	≤0.032	≤0.065	≤0.32	>0.32
Fluoride	≤1.0	≤1.0	≤1.0	≤2.0	>2.0
Cr^{6+}	≤0.005	≤0.01	≤0.05	≤0.1	>0.1

Source: "Reports on Xian's environmental quality, 1997"

2.2.3 Conclusions on water environmental quality

- Rivers are contaminated at large with a typical character of organic pollution, and the water quality of most rivers is inferior to the grade V when they reach the downtown areas

The pollutants in all of the 28 sections under supervision perennially have exceeded the national standard more or less. That is to say, rivers are contaminated at large. Except the Weihe River, all other rivers under supervision perennially originate from the Qinling Mountain range. Before they disgorge from the mountain range, the water quality is generally good. Most of them can reach the grade I according to the national standard, and few indexes reach grade II or III, such as permanganate index, volatile phenol index, petroleum index and chromic index and so on.

But after they disgorge from the mountain valleys their water quality deteriorates sharply, especially after flowing through towns or industrial centers. The main pollutants are permanganate index, BOD_5, and volatile phenol and petroleum index, of which the rate exceeding standard are 82%, 71%, and 96% respectively.

- Groundwater quality is passable except in a few local areas

The groundwater quality becomes inferior from south to north, from the low mineralized water under 1000 $mg \cdot l^{-1}$ to about 2000 $mg \cdot l^{-1}$ when reaching the city proper zone and the sewage irrigation zone in north suburb. As for the confined ground water, the man-made pollution is slight.

The aggravated ground water pollution can be retrieved back to the low rates of sewage treatment and industrial wastewater treatment.

2.3 Water supply and water purification infrastructure

2.3.1 Water supply infrastructure

In Xian there are 7 water plants (waterworks) that belong to the Xian Running Water Company and supply running water for domestic and commercial as well as industrial uses in Xian city proper. Besides, many institutions and enterprises have their own water supply systems that serve themselves with running water.

- General situation of water supply

  Water supply infrastructure in Xian is composed of ground water and surface water sources and water purification stations (waterworks). Till June 30, 1995, the maximum water supply capacity of Xian's waterworks was 720×10^3 $m^3\cdot d^{-1}$. Among them, five waterworks pumping groundwater as water sources can supply 520×10^3 $m^3\cdot d^{-1}$, and the other two waterworks either pumping surface water or groundwater can supply 200×10^3 $m^3\cdot d^{-1}$. There were totally 756 wells, which hold a power of water pumping for 1.176×10^6 $m^3\cdot d^{-1}$. The average water supply capacity by the Company was 600×10^3 $m^3\cdot d^{-1}$, taking about 68% of the total supply capacity. All the water supplied by those waterworks was purified according to the *National water quality standard* before letting it go out into the aqueducts.

  The total length of the aqueducts -pipe network- for water transfer was over 1155 km, with an area of about 142 km^2 that can serve 94.1% of the population for running water supply. Thus, the water supply in Xian has a layout of depending mainly on the ground water and having many water sources and waterworks.

  Heihe River Water Diversion Work project has being changing the state of water supply in Xian from 1996 on. The Qujiang Lake water purification station belonging to the Diversion Work has already been built, which hold a capacity of water purification accounting for 800×10^3 m^3 daily. Meanwhile, the canal of the Diversion Work has also been built partly, which can divert runoff from Heihe River, Fenghe River, and Shibianyu River to Qujiang Lake station for about 80×10^3 $m^3\cdot d^{-1}$ at present.

  In 1997, the actual water supply was $373.65\times10^6 m^3$, an equivalent water extraction of $1.024\times10^6 m^3\cdot d^{-1}$. Among it the supply of surface water reached 169.7×10^6 m^3, accounting for 45.4% of the total water supply. Therefore, the water supply composition has changed step by step from the old structure of giving priority to the underground water to the new form of both underground water and surface water half-and-half.

- Technology of the waterworks

  The technological process of most waterworks in Xian is similar: Water is pumped out from wells into the reservoir -a big water tank- where after chlorination the purified water is transferred through urban aqueducts to terminal users. While the technological process of the Qujiang Lake waterworks is another type: The water from several runoff sources in the piedmont of Qinling Mountain ranges is converged through the canal to the reservoir of the waterworks, where after coagulation-sedimentation-filtration, the purified water is transferred through aqueducts to terminal users.

- Problems in urban water supply

Most wells owned by institutions and enterprises pump the confined groundwater because the underground water is polluted. However, over exploitation of the confined ground water has resulted in the ground subsidence and the speed-up of ground cracks as well as quick drops of the confined ground water level. This in turn resulted in the decrease of water pumping amount to only $200\times10^3\ m^3\cdot d^{-1}$ (while the capacity is $280\times10^3\ m^3\cdot d^{-1}$). In fact, the pumping amount of groundwater is decreasing in all the wells around the city belt year after year.

2.3.2 Status and prediction of water demand

According to the statistical data from 1982 to 1993, the annual increasing speed of water demand is 5.1%, while the increasing speed of water supply capacity is only 2.4%. Thus, the water deficit is more and more prominent (Table 5). At present, Xian is among the cities with the largest deficit of water supply in China.

Table 5 Average rate between water supply and demand in Xian from 1982 to 1993

Year	1982	1986	1987	1988	1989	1990	1991	1992	1993
Ratio of water supply/demand	0.71	0.78	0.70	0.65	0.60	0.70	0.66	0.63	0.56

Source: "Xian's urban water supply engineering planning", 1995

Table 6 Prediction of domestic water demand

Item	1995	2000	2010	2020
Urban permanent population ($\times10^6$ persons)	2.15	2.70	3.00	3.22
Urban floating population ($\times10^6$ persons)	0.538	0.625	0.900	0.975
Rate of population with water supply (%)	97	98	100	100
Total population with water supply ($\times10^6$ persons)	2.62	3.32	3.90	4.20
Quota of water supply ($l\cdot psn^{-1}\cdot d^{-1}$)	185	210	250	260
Water demand ($\times10^3\ m^3\cdot d^{-1}$)	485.2	645.7	975.0	1098.5

Source: "Xian's urban water supply engineering planning", 1995

The water demand in Xian for next 10 to 20 years has been predicted by the Xian General Urban Planning Team with consideration on many aspects, including the population growth, industrial increase speed, GDP increase speed, domestic and industrial water consumption indexes, and improvement of technology and renewal of equipment in main agricultural and industrial sectors (Table 6, Table 7 and Table 8).

Table 7 Prediction of industrial water demand

Item	1995	2000	2010	2020
Industrial output value in city proper ($\times 10^9$ RMB yuan)	16.9	21.7	29.8	44.1
Quota of water consumption per unit value ($m^3/10^4$ RMB yuan)	158	156	140	130
Industrial water demand per year ($\times 10^6\ m^3 \cdot a^{-1}$)	267.02	340.69	401.66	572.78
Industrial water demand per day ($\times 10^3\ m^3 \cdot d^{-1}$)	731.6	933.4	1141.5	1569.3

Source: "Xian's urban water supply engineering planning", 1995

Table 8 Present and predicted total water demand in Xian city proper (Unit: $\times 10^3\ m^3 \cdot d^{-1}$)

Item	1990	1995	2000	2010	2020
Residential water demand (Q_1)	333.4	485.2	645.7	975.0	1098.5
Industrial water demand (Q_2)	555.1	731.6	933.4	1141.5	1569.3
Total ($Q_3=Q_1+Q_2$)	888.5	1216.8	1579.1	2116.5	2667.8
Supply capacity by institutions and enterprises themselves (Q_4)	280	200	140	140	140
Supply capacity needed from municipal administration ($Q_5=Q_3-Q_4$)	608.5	1016.8	1439.7	1976.5	2527.8
Water demand of municipal engineering and greening ($Q_6=Q_5\times 0.02$)	12.17	20.34	28.79	39.53	50.56
Average water demand* ($Q_7=(Q_5+Q_6)\times 1.08$)	670.3	1120.1	1585.3	2177.3	2784.6

* Plus 8% urban aqueducts-pipe network-loss in transfer

Source: "Xian's urban water supply engineering planning", 1995

2.4 Technological options of wastewater treatment system

2.4.1 Wastewater treatment system

There are two wastewater treatment plants in Xian at present. One is Beishiqiao Sewage Purification Center; the other is Dengjiacun Sewage Purification Plant. The former is situated in the western suburb and the latter in the northwestern corner of the city proper. They totally hold a capacity of 270×10^3 $m^3 \cdot d^{-1}$ for treating domestic sewage or industrial wastewater. Besides those two plants, there are many small primary wastewater treatment systems owned by institutions and enterprises. They distribute evenly in city proper areas except in downtown area of inner city and their capacity reaches to 180×10^3 $m^3 \cdot d^{-1}$. Thus the total capacity of wastewater treatment in Xian is about 450×10^3 $m^3 \cdot d^{-1}$, accounting for 50% of the total wastewater generated daily.

2.4.2 Beishiqiao Sewage Purification Center

Beishiqiao Sewage Purification Center is one of the major environmental projects completed in recent years. With a total investment of 210 million RMB, its designed capacity is 150×10^3 $m^3 \cdot d^{-1}$ (its long-term capacity being 300×10^3 $m^3 \cdot d^{-1}$). It serves a total area of 53.5 km^2 with planned population of 600,000 (after the fulfillment of the second phase of the project). The sewage collected by the intercept pipes in the southwest suburbs, flows into the Center for purification.

The Center, a project co-operated technologically between China and Denmark, has applied the foreign loan of 5.45 million US$ and imported its major equipment and instruments from the I. Kruger Engineering AS Denmark. Its construction started in October 1994 and was completed in December 1997. In May 1998 it was put into operation. The volume of the hydraulic structure amounts to 1.08×10^5 m^3 and the total design power is 6300 kW.

The sewage treatment system adopts the technology of DE oxidation ditch. The vertical pump lifts raw sewage to the single-pipe outlet well through coarse bar screens. After such treatments as fine screening, aerated grit chamber, oxidation ditch, final settling tank, etc., it enters the chlorination tank for disinfection before being discharged to the Zaohe River. Part of the treated water is recycled inside the Center. The operation shows that the removal of SS, BOD_5, COD, NH_3-N is all over 90%. The project has already achieved its initial investment benefits.

2.5 Future strategy of water resources and countermeasures on water pollution

The water resources and water environment are two interrelated sides for one matter. Therefore the strategies of water resources and the countermeasures on water pollution are also two interrelated solutions for the same problem -the water shortage- in Xian City.

2.5.1 Strategies and prospects of water resources

Because Xian is a city without much water resources and the present level on water resources utilization is rather high, the potential to raise the utilization level in the city proper is limited. The solution of the problem, just as mentioned before, lies in two ways: One is to divert water resources from other watersheds in Qinling Mountain ranges and the other is to raise the recycling use of treated wastewater.

- Water diversion works

The water diversion works in Xian mainly refer to the Heihe River Water Diversion Work and related waterworks. After finishing its construction in 2002, the Work can raise water supply capacity for Xian with an amount of 550×10^3 $m^3 \cdot d^{-1}$ and alleviate the water deficit pressure in city proper until year 2010.

- Heihe River water diversion work project

Heihe River water diversion work project which is being under construction aims mainly at the water supply for Xian city proper, and is a big surface water project including three main parts. They are the urban water supply canal, the Jinpen reservoir, and the irrigation systems, with multi-purposes like farmland irrigation, power generation and flood control. Heihe River water diversion work project has five water sources, of which Heihe River is the primary one and located in the Zhouzhi County, southwest part of Xian City. The rests include Shitouhe River, Tianyu River, Fenghe River, and Shibianyu River. They are converged from west to east through a canal 89 km long to the Qujiang Lake Water Station in the south suburb of Xian. In sum, the water quality in Heihe River is very good for all kinds of water use and its only pollution threat comes from the non-point source pollution caused by the rainfall runoff.

- Economization of water use

The projected economization of water use lies mainly in the recycling use of wastewater after complete treatment. This is under tentative practice in several industrial enterprises and will be popular after year 2000. At present the first thing to do is to spread this practice to all of the industrial sectors and formulate a series of regulations and policies with economic instruments for promoting this practice among all the society.

- Prospects of water resources

According to the projected planning on Xian City's development, the population will reach 3.3×10^6 in city proper in year 2000 and 3.8×10^6 in year 2010. Meanwhile, the GDP will reach ￥71.8×10^9 RMB yuan (US$ 8.8×10^9) in city proper in year 2000 and ￥143.7×10^9 RMB yuan (US$ 17.5×10^9) in year 2010. This means that the water demand for both residential, and commercial and industrial will be 1.9024×10^6 $m^3 \cdot d^{-1}$ daily in the year 2000 and 2.5039 $m^3 \cdot d^{-1}$ in the year 2010. There is, as we know, not so much water supply capacity in Xian. The ultimate feasible solution for this problem is to dig a tunnel through Qinling Mountain ranges and divert water from Xushuihe River, a large tributary of Hanjiang River belonging to Yangtze River system, to Heihe River and then to Xian through the canal of Heihe River water diversion work. And if it is successful, the water shortage history in Xian will be ended forever.

2.5.2 Countermeasures on water pollution

Reducing the water pollution and improving the water environment can not only better the whole environmental quality, but also help to release the pressure of water shortage somewhat in Xian City. For doing this there are two ways: One is to construct more wastewater (sewage) treatment plants and the other is to apply advanced technology and to practice water-saving production in all enterprises.

- Construction of wastewater treatment system

According to the projected planning on Xian City's development, there will be seven big wastewater treatment plants in the year 2010. Besides those two already constructed and put into operation, the other five are under designing or projecting (Table 9).

Table 9 List of projected urban sewage treatment system in Xian City

Item	Treatment level	Year of operation		
		1995	2000	2010
Capacity and level of treatment ($\times10^3 \cdot m^3 \cdot d^{-1}$)	Dengjiacun (secondary)	120	160	270
	Beishiqiao (secondary)		150	370
	Dianzicun (primary)		200	400
	Yuanlecun (secondary)			290
	Fangzhicheng (secondary)		40	80
	Liucunbu (secondary)			110
	Weiqu (secondary)		50	100
Total treatment capacity ($\times10^3 \cdot m^3 \cdot d^{-1}$)	Secondary	120	400	1220
	Above primary	120	600	1620
	Reuse after treatment		80	190
Wastewater discharge ($\times10^3 \cdot m^3 \cdot d^{-1}$)	Residential sewage	310.5	585.2	889.6
	Industrial wastewater	526.7	789.5	1255.0
Rate of treatment (%)	Secondary	14.3	29.1	56.9
	Above primary	14.3	43.6	75.5
Pollutant reduced ($t \cdot a^{-1}$)	COD	8910	39600	110385
	SS	10296	47520	131076

Source: "Xian's long-term (year 2010) environmental protection planning", 1996

From the Table 9, we can see that more than half of the wastewater will be treated at the secondary level and three fourth at the primary level in the year 2010. And till then the wastewater that can be reused increases to $190\times10^3 m^3 \cdot d^{-1}$, being equal to 9% of the total water demand.

After the full operation of those wastewater treatment plants, the quality of surface water will be improved in much extent. And also the quality of ground water will be much better than that at present along with the improvement of the quality of surface water because the quality of ground water is controlled mostly by the replacement from surface water.

- Application of advanced technology in industrial sectors

The discharge amount of the industrial wastewater at present is about 1.5 fold of the urban residential sewage. This is so not only by the industrial scale but also by the technology applied in many industrial enterprises. So there is an urgent need to phase-off the backward technology and obsolete equipment that discharges more pollutants and consumes more water in the process of production. There is also an urgent need to introduce advanced technology from both at home and abroad to develop water-saving production or "clean-production". The principle of "keeping pollution controlled by whomever making" -polluter pays principle- should be strengthened and the focal points should be put in the context of "polluters get punishment, innovators get award and destroyers do the recovery." To implement all above countermeasures thoroughly, simply the best way is to raise the water prices at two ends: One in water supply and the other in wastewater discharge.

3. Urban Traffic Problem and Its Solution

The other urgent problem encountered in Xian City in recent years, is the crowded urban traffic and thus serious noise and air pollution due to a relatively undeveloped urban traffic system. Here we will probe into the causes leading to the urban traffic deterioration, and try to put forward some "software" managerial strategies for solving the problem.

3.1 Current status of communication and urban traffic in Xian City

3.1.1 Main lines of inter-city communication and transportation

Xian City is one of the most important traffic hubs in China. It is a strategic passage and also a pivot connecting the eastern, north-western and south-western regions of china (Table 10 and Fig. 3).

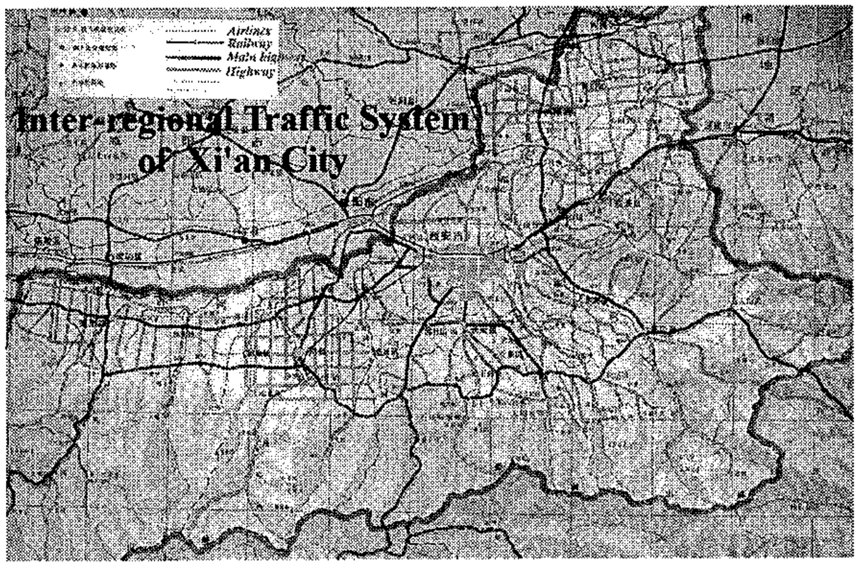
Longhai railway passing Xian is a main line, which connects Baocheng, Baozhong, Lanxin and Baolan, Lanqing, Tongpu, Xiyan, Jiaozhi, Jingguang, Jingjiu Jinhu railway lines. Xian is connected through this line to Beijing, Tianjin, Shanghai, and Chongqing directly as well as to other 9 provincial capitals of China.

Table 10 Main indices of transportation in Xian in 1996, 1997

Item		1996	1997	Growth rate in 1997 (%) (compared with 1996)
Passenger traffic	Railways (×10⁴ person-times)	2754	2015	-26.84
	Highways (×10⁴ person-times)	6802	6581	-3.25
	Civil aviation (×10⁴ person-times)	298	326	9.39
Passenger-kilometers	Railways (×10⁶person·km)	13902.53	13449.33	3.26
	Highways (×10⁶person·km)	1497.49	1861.52	24.30
	Civil aviation (×10⁶ person·km)	3974.38	4122.82	3.73
Freight traffic	Railways (×10⁶t)	34.77	31.84	-8.43
	Highways (×10⁶t)	70.95	61.67	-13.08
	Civil aviation (×10⁴t)	5.13	6.48	26.31
Freight Ton·kilometers	Railways (×10⁶t·km)	31595.48	31975.99	1.20
	Highways (×10⁶t·km)	2169.52	2422.00	11.63
	Civil aviation (×10⁶t·km)	63.29	97.50	54.05

Source: "Statistic Yearbook of Xian, 1998

Fig. 3 Inter-regional traffic system and transportation network of Xian



Source: "Atlas of Xian City, 1989"

Road transportation also plays an important role. There are 5 national and 11 provincial highways passing Xian, such as Beijing to Kunming, Baotou to Nanning, Yingchuan to Xian, Lianyungang to Tianshui and Shanghai to Yining. The road can reach big cities like Lanzhou, Zhenzhou, Taiyuan, Beijing, Wuhan, Nanjing and Shanghai etc. The airlines in Xian can reach to most provincial capitals and big cities of China, and in Xian there are international airlines reaching to Japan, Hong Kong, and Macao, too.

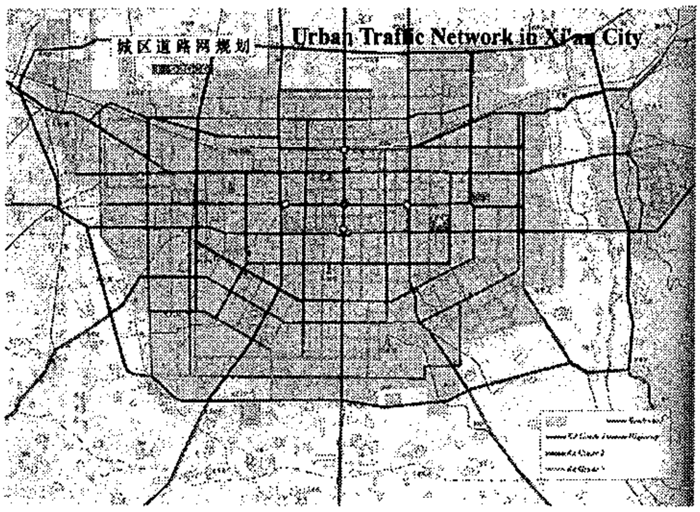
3.1.2 Urban traffic network (Intra-city traffic and transportation roads)

Urban traffic network in Xian inherited and developed from the style of Changan City, capital of Sui Dynasty and Tang Dynasty, which paid much attention to symmetry and proportion, and thus is a chessboard like, combining the needs of transportation for a contemporary city with the topography of Xian. The network formed the layout with squares, circles and radiation lines, which consists of two axes, three circles and eight artery avenues as its backbone frame (Fig. 4).

The urban traffic road system is divided into four grades plus an urban tour-scenic road. Three circles and eight artery boulevards are the first grade roads (in red). The second grade (in blue) includes regional roads. The third grade (in light blue) consists of roads in residential areas. The small and local lanes belong to the fourth grade roads.

The inner circle and the second circle are the main urban traffic roads (in red), which connect all parts of the city proper. The outer circle (third circle, in red) is the traffic hub that connects Xian to state highways, provincial highways, and regional roads (in orange) in Guanzhong region, Shaanxi Province. In order to protect ancient cultural sites, a tour-scenic boulevard along the western, southern and eastern city wall ruins of Tang Dynasty has been planned and constructed (in green). This road permits only tourist buses and walking travelers to pass by, but no freight trucks are permitted (Fig. 4).

Fig. 4 Urban traffic network in Xian



Source: "Atlas of Xian City, 1989

3.1.3 Unbalanced layout of urban traffic roads and bus lines

The road layout of Xian has three characteristics, which in much extent does not tally with the ever-increasing urban traffic. Firstly, there are two artery roads in downtown area for east-westward traffic flow, which provides a favorable traffic condition for inner areas to go outside the city. But this also results in that all the vehicles have to pass through the downtown areas even if they only want to pass by Xian from this side to other side or vice versa. Secondly, the urban traffic network takes Zhonglou (Bell Tower) as their central starter, radiating to all parts of the urban area. This means that most of the bus lines concentrate in downtown area of inner city, resulting in an over-crowded urban center and a comparatively inconvenient traffic in outskirts. Thirdly, there is neither metro nor other rail commuter system in Xian to offer a rapid urban traffic system for abating the ever-increasing heavy traffic in downtown area.

3.1.4 Comparison of urban traffic between Xian and some other cities in China

To further have a background impression on the current urban traffic situation in Xian City, let's make a comparison between Xian and some other cities in China (Table 11).

Table 11 Urban traffic situation in some metropolises in China

City	Geographic location	Urban traffic system	Population density (people·km^{-2})	Possession of trolleys & buses per 10^4persons (vehicles)	Road acreage per capita (m^2·person^{-1})
All cities			296	2.8	2.9
Beijing	Near coastland	Grade separation, with metro	1614	9.3	4.7
Tianjin	Coastland	Grade crossing	1368	4.3	6.0
Shanghai	Coastland	Grade separation, with metro	4672	11.8	5.4
Nanjing	Near coastland	Grade crossing	2760	8.8	5.4
Qingdao	Coastland	Grade crossing	2031	9.0	6.0
Guangzhou	Near coastland	Grade crossing, with metro	2702	9.6	5.2
Xian	Hinterland	Grade crossing	2845	3.8	3.5
Lanzhou	Hinterland	Grade crossing	1035	5.6	5.2

Source: "Urban Statistical Yearbook of China, 1997" (Data only in city proper, up to the end of 1996)

From the Table 11, we know that in Xian the population density is higher, the vehicle possession lower, and the road acreage smaller than that in many other cities. Compared with Lanzhou, for example, also a hinterland city in even further west, Xian falls much behind, not to speak of with those other economic-booming cities in southeastern part of China.

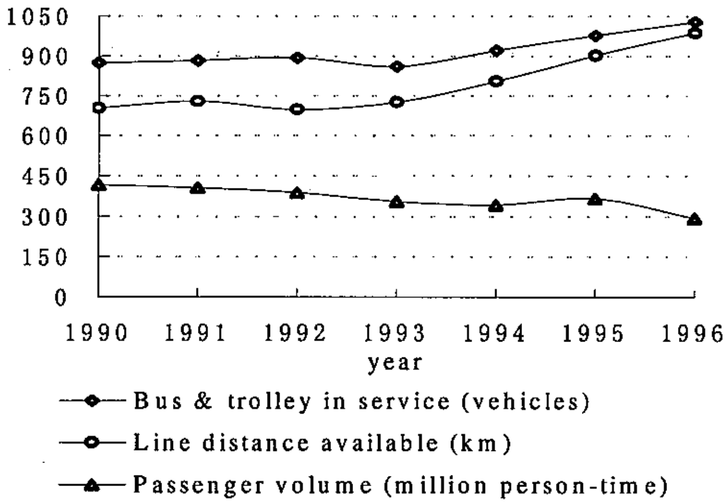
Dense population, low vehicle possession and small road acreage would undoubtedly exert high pressure on urban traffic.

3.1.5 Public traffic service in city proper

The urban public traffic service in Xian has been relying mainly on the buses and trolleys. In recent years, the improvement of urban public traffic in city proper has been stagnant. Although the mileage of bus lines and the number of bus vehicles in service have increased somewhat, the passenger volume has been declining during the period of 1990 to 1996 (Fig. 5).

Besides bus line's route setting and distribution, service time, management level and vehicle mechanic maintenance, the cause of passenger declining might relate to the ever-increasing numbers of taxi and private motorcycles or cars, each of which has driven part of passengers away. Although this "driven away" alleviated the difficulty of riding on a bus, the immediate result of this was more traffic jam, lower vehicle speed, more fuel or power consumption, and more accidents than ever before (Table 12).

Fig. 5 Public transportation in Xian



Source: "Statistical Yearbook of Xian, 1990-1998

Table 12 Rising traffic cost in city proper

Year	Taxi in service (vehicles)	Fuel consumption per bus (L/100km)	Power consumption per trolley (kW·h/100km)	Loss by traffic accidents ($\times10^6$ US $)
1991	4494	25.46	93.05	0.3231
1992	5068	26.09	94.36	0.4298
1993	7487	32.73	93.71	0.6781
1994	8761	34.20	95.80	0.9293
1995	9814	35.70	97.30	1.0081
1996	9825	33.50	89.10	1.1340

Source: "Statistical Yearbook of Xian, 1992, 1993, 1994, 1995, 1996, and 1997"

3.1.6 Traffic flow and road construction

The traffic flow on main roads in city proper is going up steadily in recent years due to the fast expansion of motor vehicles and slow road construction (Kang 1998). Up to the end of 1996, the numbers of motorcars have increased to over 200000 vehicles and non-motored vehicles over 3000000, which means an annual increase speed of more than 10%. In contrast, the road construction was sluggish and its annual increase speed was only 4% during the same period (Table 13).

Table 13 Urban traffic flux, urban roads and public traffic lines

Year	Urban traffic flux on main roads (vehicles·h^{-1})	Average width of main roads (m)	Length of total urban roads (km)	Acreage of total urban road ($\times10^6 m^2$)
1990	597	19.3	1069	10.20
1991	648	19.8	1080	10.42
1992	687	19.8	1121	11.23
1993	910	20	1123	11.30
1994	1050	20	1472	12.81
1995*	1256	23.3	835	10.22
1996	1383	25	869	10.70
1997	1489	24	911	11.42

Source: "Statistical Yearbook of Xian", 1995, 1998

* The calibration of urban road changed from 1995.

3.1.7 Economic restructuring and traffic jam

In recent years, many people left their original working positions due to the economic restructuring (which led to the rising unemployment rate). Those people who left their original positions had to find a new job by themselves and normally got one only in the category of tertiary industry such as a peddler or a catering trader. Very often those self-employed laborers took up the sidewalks on downtown area as their business sites. This resulted not only in the food leftover pollution along roadsides but also crowded traffic in downtown area, because pedestrians were forced to walk along on the roadway and non-motor vehicles to drive on the inside lane, leaving no path for motor vehicles passing by. From the analysis above, we know that the urban traffic situation in city proper of Xian is rather serious. And the crowded traffic has led to a serious environmental pollution as well.

3.2 Environmental pollution induced by crowded traffic

3.2.1 Traffic noise pollution

The results of environmental monitoring have shown: In recent years the traffic noise keeps at a very high level and is the principal source of the noise pollution in city proper (Environmental Protection Bureau of Xian City. 1996, 1997). The L_{90}, a statistical indication of the background level of traffic noise, has increased from 62 dB(A) in 1991 to 66 dB(A) in 1995 (Table 12). Although it was down to 63 dB(A) due to some traffic management measures implemented by Urban Traffic Management Bureau of Municipality in 1996, the average equivalent sound level (L_{eq}) of traffic noise kept still at 71.1 dB (A) and average peak level (L_{10}) 74 dB (A). On 62% of the main roads in city proper, the L_{eq} of traffic noise surpassed the level of 70 dB (A) at daytime, an internationally accepted environmental standard for traffic noise (Table 14 and Table 15).

Table 14 Urban traffic noise in Xian

Year	Number of monitoring point	Length of monitoring (km)	Average width of road (m)	Urban traffic flux on main roads (vehicles·h^{-1})	L_{eq}	L_{10}	L_{50}	L_{90}
1990	214	215.377	19.3	597	72.0			
1991	210	213.037	19.8	648	72.6	75	68	62
1992	199	209.060	19.8	687	71.6	74	67	61
1993	195	203.719	20	910	70.1	72	66	61
1994	198	207.449	20	1050	70.5	74	68	63
1995	202	213.819	23.3	1256	71.8	75	68	66
1996	150	194.037	25	1383	71.1	74	68	63
1997	153	198.757	24	1489	70.1	73	66	61

Source: "Reports on the environmental quality of Xian", 1991–1995, 1996 and 1997

Table 15 Traffic volume on main roads and the pollution caused by traffic

Year	Urban traffic flux on main roads (vehicles·h^{-1})	Background level of traffic noise (L_{90}, dB(A))	Mean daily concentration level of NO_x (mg·m^{-3})	Annual rate of mean daily concentration of NO_x over the atmospheric quality standard* (%)
1991	648	62	0.059	12.7
1992	687	61	0.058	7.1
1993	910	61	0.058	8.3
1994	1050	63	0.040	3.8
1995	1256	66	0.056	13.5
1996	1383	63	0.053	11.6

* Levels at 0.10 mg·m^{-3} for NO_x (Grade 2, Editors' Board of "A Grand Dictionary of Environmental Sciences", 1991).

Source: "Reports on the environmental quality of Xian", 1991–1995, 1996.

The overall noise radiated by traffic vehicles is directly related to the traffic flow. Normally, the traffic noise measured a few meters away from a road increases by 3 dB(A) for every doubling of traffic flow (Kupchella and Hyland 1986). Up to the end of 1995, the figure of traffic flux on main roads in city proper has nearly doubled compared with that in 1991 (Table 15). No wonder that the noise pollution was serious.

3.2.2 Motor vehicle exhaust pollution

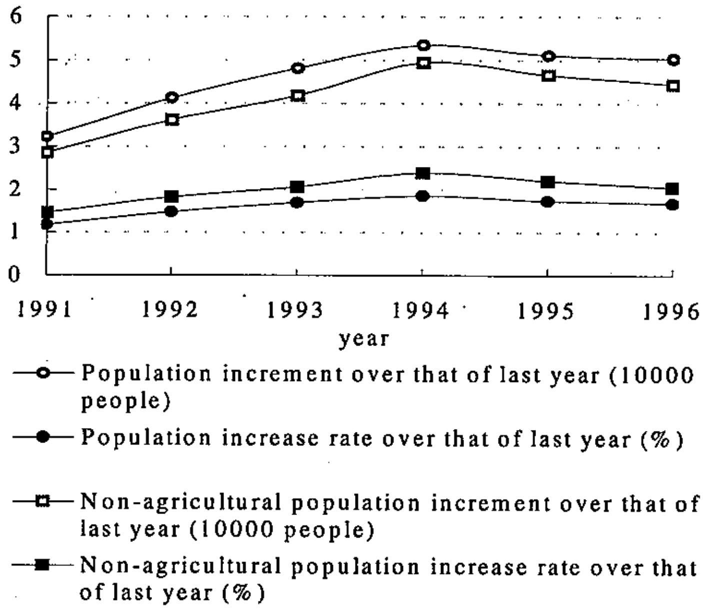
The crowded traffic has led not only to the noise pollution, but to the air pollution as well. In recent years, the mean daily concentration of NO_x kept at levels between 0.040–0.059 mg·m^{-3}, nearly all of which were over 0.050 mg·m^{-3}, grade I of the national atmospheric quality standard for NO_x except in 1994 (Table 15). Meanwhile, each year there were many days in which the mean concentration of NO_x was over grade II. The annual highest rate of over–standard–day happened to be in 1995. Especially in November of that year, the monthly rate of over–standard–day surpassed 52.5%. Judging from most part of NO_x in the air over the downtown area of Xian comes from the motor vehicle's exhaust, the NO_x pollution in the future would probably be more severe than before, because there has already been an accelerated trend of expansion of motor vehicles in Xian.

3.3 Causes leading to crowded traffic and pollution

3.3.1 Uncontrolled mechanic population growth

Urban development itself and people yearning for an urban living, meaning more convenient and colorful life as well as better opportunity for employment, continuously drive the rural residents to city proper, which now becomes an immigration trend and results in the fast mechanic population growth in Xian city proper.

Fig. 6 Population growth in Xian city proper



From 1990 to 1996, the yearly natural population growth in the city proper kept at 0.50–0.75% and the trend of fast population growth was under control. The yearly mechanic population growth, the immigration, however, was still rather high and figured at 1.2–1.8% during the same period. The non-agricultural population, growing even more rapidly, had mechanically increased by 12.6% in city proper from 1990 to 1996, which means a net increment of 30–50 thousand people each year or an annual 2.1% increase on the average (Fig. 6).

Along with a faster pace of urbanization and thus a more rapid immigration of surplus labor force from rural area to city proper, this high mechanic population growth will still keep for a long period of time, though the natural population growth is low.

On the contrary, the municipality has not effectively brought the trend under full control, for those labor force can bring in considerable economic returns each year for the City. Thus the real point is that the municipality has not given enough considerations on the construction of urban traffic facilities to cope up with the trend.

3.3.2 Other managerial causes

- Non-integrated urban infrastructure construction. In recent years, the major concern on urban infrastructure construction has been focusing on power and water supplies as well as telecommunication, in order to improve the "investment environment" for inducing overseas investments and developing export-oriented economy. This is right. But the urban traffic system that was neglected to enhance is also a part of and integrated to the "investment environment".

- Near-sighted investment policies. The construction projects that are easy to get investments have been concentrated on those that are short-term and thus can get immediate gains, or that have already come into a virtuous circle and thus can get long stable returns, for example, telecommunication and inter-city highways. The urban traffic system, however, nearly reaches its saturation point and can not be fully improved unless developing a grade separation traffic system with overpasses and/or metro system. The funds for the construction of a grade separation traffic system, however, are too immense to attract investments from all over the society at present. But in the long run, a grade separation traffic system can radically change the urban traffic situation and improve the Xian's image, which in turn can bring in new investments and thus profit returns. It is worth while considering how to attract investments for the construction of a grade separation traffic system.
- Indifference to the environmental protection among some decision-makers. Pollution is a typical behavior of external cost. Market economy mechanism has innate defect with regard to the environmental protection. It needs the interference by government through formulating a series of environmental policies to get the environmental targets. Those targets, however, are considered only as a "soft index" of achievements in governors' official career by some decision-makers. They hold the view that the environmental harnessing can not get much tangible returns at their terms of office and thus need not be paid much attention to.

3.4 Proposals for improving the urban traffic situation

The above-mentioned crowded traffic and its direct result of serious noise and NO_x pollution often happened in the beginning stage of "economic take-off" in cities around the world. In other words, we can draw lessons from those cities and find a better way to coordinate economic development with urban traffic improvement and environmental protection.

The ultimate solution of the urban traffic problem, of course, is to raise funds and investments for "hardware" construction, i.e., for the construction of new roads and a grade separation traffic system. But at the beginning stage of "economic take-off" in Xian, there are some difficulties for municipality to finance and allocate more funds for the construction of new roads and a grade separation traffic system. There is, however, room for a "software" solution. In order to alleviate traffic jam, for example, the Urban Traffic Management Bureau of Municipality of Xian has managed to implement one-way road policy in several main roads since November 1995. This measure has diverted vehicles of different driving directions to different roads, raised vehicles' driving speed greatly, and thus expanded the traffic capacity on those roads (Xian Statistical Bureau 1997). Therefore, the rising trend of vehicles' fuel and power consumption was brought under control and the noise pollution induced by urban traffic was got down somewhat in 1996, though traffic flux on main roads was still on the rising (Table 12, Table 15). This means that through formulating suitable managerial policies and implementing proper economic instruments in urban traffic management practices the urban traffic problem can be solved or at lest be partly solved. According to that logic, the following proposals for improving the urban traffic situation in city proper seem to be feasible:

3.4.1 Proposals for traffic management policies

- In the central business district and a few crowding downtown areas, divert public mass traffic from automobile traffic as well as non-motor traffic, keep time and pass limitations against automobile traffic at the traffic peaks, and draw up some walking–streets if need.
- In city proper, extend mass traffic service hours, reset some irrational bus line's distribution, and increase express bus and trolley lines to expand the traffic capacity. Meanwhile, enlarge mass traffic vehicle numbers, improve mass traffic service quality, and encourage citizens to take on mass traffic.
- In both sides of road designate special parking lines and charge high parking fee on heavy traffic areas and/or times. Draw up more one-way roads, and control taxis' quantity strictly and limit their driving routes on daytime.
- Practice motorcars with little cylinder displacement driving to downtown area on every other day. Levy extra taxes on motorcars with large cylinder displacement or with heavy polluting discharges, to help raise funds for constructing new roads and widening old ones.
- Promote the consciousness of obeying traffic regulations among citizens through ways like consultation, traffic information services, and traffic regulation training programs. Meanwhile, strengthen the rewards for obeying regulations and punishments for violating regulations with reasonable economic levers.

3.4.2 Proposals for municipal administration and environmental management

- Reallocate and extend business hours in commercial quarters and service trades to divert customers and avoid traffic peak. At the same time prohibit those peddlers or individual catering trades from occupying sidewalks or roadways by delimiting special sectors for them.
- Forbid automobiles' blowing and whistling in downtown areas, enhance the examination on motorcars' exhaust check, and encourage the installation of exhaust purifier and use of lead-free gas so as to protect urban environment.
- The last but not the least, and one we must insist on, bring the mechanic population growth under full control. In particular, strictly check the speed and scale of immigration from rural residents to urban dwellers, and sternly implement the phasing in employment of surplus farm labor force into non-agricultural occupations in downtown areas. To do this, it is needed guiding the urbanization

from city proper to suburban areas or satellite towns around Xian. This can be done by way of encouraging entrepreneurs and businessmen to establish enterprises and businesses at township areas, so as to divert surplus farm labor force get employed in non-agricultural occupations at their hometowns. In other words, make a balanced urban development in Xian so as to alleviate the urban traffic pressure in city proper in the long run.

References

Department of Geography, Shaanxi Normal University. (1988) Records of Xian's History. (in Chinese), Shaanxi People's Publishing House.

Editors Board. (1991) A grand dictionary of environmental sciences (Chinese Edition), China Environmental Science Publishing House, Beijing, 1056pp.

Editorial Commission of the Atlas of Xian City. (1989) Atlas of Xian City. (in Chinese) Xian Atlas Publishing House.

Editorial Commission of the Urban Construction in Modern Xian. (1988) The Urban Construction in Modern Xian. (in Chinese), Shaanxi People's Publishing House.

Editorial Committee of Annals of Local History of Xian. (1996) Annals of Xian City. Volume I: Generalization. (in Chinese), Xian Publishing House.

Environmental Protection Bureau of Xian City. (1990) Report on the environmental quality 1985–1990, (in Chinese).

Environmental Protection Bureau of Xian City. (1996) Report on the environmental quality 1991–1995, (in Chinese).

Environmental Protection Bureau of Xian City. (1997) Report on the environmental quality 1996, (in Chinese).

Environmental Protection Bureau of Xian City. (1998) Report on the environmental quality 1997, (in Chinese).

Kang, Muyi. (1998) On the discordant urban development in Xian City. *Economic Management* (6): 36-37 (in Chinese).

Kang, Muyi. (1998) Population Growth and Urban Traffic Problem in Xian City. *Economic Geography* 18 (5): 131-136 (in Chinese).

Kupchella, Charles E. and Margaret C. Hyland. (1986) Environmental science. Allyn and Bacon, Inc. Boston, 589pp.

Liu, Shuo and Kang Muyi. (1997) Discussion on Approaches of Sustainable Water Resources Utilization for Xian City. (Editor In Chief, Chen Zongxing: Regional Environment and Sustainable Development, in Chinese). Northwest University Publishing House.

Ma, Naixi et al. (1999) Research into the Eco-environmental Construction in Xian City. (in Chinese), Xian Atlas Publishing House.

Urban Societal and Economic Survey Team, State Statistical Bureau. (1998) Urban statistical yearbook of China 1997. (in Chinese), China Statistical Publishing House, Beijing, 626pp.

Xian Statistical Bureau. (1989) Forty Years in Xian (1949-1989). (in Chinese), Shaanxi News Publishing Bureau.

Xian Statistical Bureau. (1992–1999) Statistical yearbook of Xian, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997 and 1998. (in Chinese), China Statistical Publishing House, Beijing.

Xian Statistical Bureau. (1995) Collection of Statistical Annals of Xian. Volume I, II, III, and IV (1949-1989). (in Chinese), China Statistical Publishing House, Beijing.

[1] 西安市土地利用总体规划，1995，西安市土地利用总体规划办公室
[2] 西安市市域城镇体系规划（1995-2020年），1995，西安市城市规划管理局，西安市城市规划设计研究院
[3] 西安市环境保护"九五"计划和到2010年长远规划，1996，西安市环保局、西安市环境保护研究所
[4] 西安市城市给水工程规划（1995~2020年），1995，西安市城市规划管理局，西安市自来水公司，西安市城市规划设计研究院
[5] 西安市排水工程规划（1995~2020），1995，西安市城市规划管理局，西安市市政工程管理局，西安市市政工程设计研究院，西安市城市规划设计研究院
[6] 城市供水，1993，西安市公用事业局
[7] 西安市城市综合交通规划（1995-2020年），1995，西安市城市规划管理局，西安市城市规划设计研究院
[8] 西安市政公用设施普查，1996，西安市建设委员会，西安市统计局

Rural Industrialization and Regional Urbanization in Jiangyin

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I. Introduction

A dramatic social, economic and environmental change has taken place at the Yangtze River Delta especially along the Suzhou-Wuxi-Changzhou corridor since China opened to the world and began the transition from a planned to a market economy and from a rural to an industrialized society. In this region, a flexible policy for development, viable decentralized institutions, a long tradition of industrialization, a strong technical support from large cities such as Shanghai, and rich human and natural resources have stimulated an extraordinary growth of the local economy.

Unfortunately, along with positive economic growth, there are also the negative significant environmental impacts. The blue water of the delta is being changed into black or colorful water because of contamination. People in many cities of this area have now to buy clean water instead of using tap water. Increasing industrial and municipal water use has changed the surface water system. The traditional landscape is being changed into an industrial landscape. The sealed ground, due to urban, industrial and traffic landuse, has blocked the vertical connection of the hydrological network also surface water pollution has increased the extraction of groundwater, cutting down connection to the groundwater network.

In order to explore how to manage the environment and to protect ecosystems during the process of urbanization and industrialization, in the Yangtze Delta, we focus on Jiangyin City as a typical city in the process of urbanization and industrialization. This study is carried out according to the model of DPSER, which includes driving force, pressure, state, effect and response.

2. Regional Background

2.1 Yangtze River Delta

The Yangtze River Delta is located on the eastern coastal area of China with a population of 73.71 million and an area of 99,530 km^2. Neighboured by the Shanghai and centered geographically by Taihu Lake, it belongs to a subtropical zone with annual precipitation from 1100 to 1400 mm, and an annual mean temperature of about 16 °C. The annual solar radiation accounts for 1.185×10^9 cal. m^{-2}. This area used to be one of the main grain production bases in China. It is one of the oldest cultivated areas for sustainable agriculture and human settlement development in China. According to historical records, rice has been planted here for 6000 to 7000 years.

There are three province-capital cities with population over 1 million, 15 prefecture-level cities, 39 county-level cities and 1392 towns in this area with a total population 73.71 million, and on urban population of 22.87 million (1993). The average population density is 741 persons/km^2. While in the built up areas of Shanghai, the population density is 40,000 persons/km^2 on average, with 80,000 persons /km^2 for half of the central area. Towns and cities in this region are distributed mainly along waterways (Yangtze River and the Great Canal) and railways, formulating an urban and industrial corridor along Nanjing - Changzhou -Wuxi - Suzhou - Shanghai and Shanghai -Hangzhou - Ningbo. The Yangtze Delta has a long history of urbanisation and industrialisation.

Since China opened to the world and began the transition from a planned to a market economy and from a rural to an industrialized society, a dramatic social, economic and environmental change has taken place in the Yangtze River Delta especially along the Suzhou-Wuxi-Changzhou corridor. This region has become one of the most rapidly urbanizing and rural industrializing areas in China. Its annual growth rate of GDP is, on average, 50% higher than that of China since 1992. City population in the region has increased by 60% and the population in small towns has increased by 2.7 times, and around 8 million labors have immigrated to this region during the past two decades. The urban area has enlarged by 60%. Meanwhile, this corridor's annual growth rate of GDP is 12.7%, 50% higher than that of China's average since 1992. Farmers' income has increased by 19 times, annually to 17.4%, while citizens' income has increased by 17 times, annually to 16.4%. City population increased by 60%, population in small towns has increased by 270% and 8 million labors immigrated into the region Urbanized area has increased by 17.57%, and traffic area has increased by 46.67%. Now the Yangtze River Delta plays a crucial role in the national economy. Its area, population, GDP and revenue are 1.04%, 6.09%, 15.42% and 21.8% of the total for China respectively. In 1992, the total industrial output value was 74.53 billion RMB yuan, 20% of that of China's.

The delta is currently the largest comprehensive industrial base in China for light textile, mechanical-electrical and chemical fiber production, and is also an important base for steel-and-iron, petrochemical and light automobile production. In some growing cities of the delta, the dominating industry has changed from a heavy chemical industry to a mechanical-electronic integrated industry, while maintaining the light textile industry. The proportion of primary industry has decreased enormously, to a much lower level than that of the national mean, but the size of secondary and tertiary industries has increased rapidly. The ratio among the primary, secondary and tertiary industries is 9.5%: 57%: 33.2%, while their labor ratio is 30:45:25. In agricultural, the output of farming, forestry, animal husbandry, fishery and agro-processing products accounts for 48%, 2%, 28%, 14% and 8% respectively. The economic development in this region is based on distributed industries, called Township and Village Enterprises (TVE), whose growth is much faster than that of cities. They have become a significant source of income for peasants.

According to the land use survey in 1993, arable land takes up 34.7% of the region, garden plots 8.9%, forestry 22.7%, grassland 0.3%, urbanized land (built up area, industrial and mining land) 8.7%, traffic land 2.2%, water-bodies 18.4% and the rest (wild land, wasteland etc.) 4.1%. Compared with that of the mid 1980s, urbanized area has increased by 17.57%, much higher than that of the state average level of 2.5%. The traffic area has increased by 46.67%. In Shanghai, the built up area was 86 km^2 in 1949, 276.35

km^2 in 1984, and 324 km^2 in the early 1990's, and 365 km^2 more will be added after the construction is finished at Pudong's new development area, in the near future. At the same time, agriculture in the region has shrunk due to the great shift of arable land into urban and industrial use. Currently, the arable land per capita in the region is only 0.13 ha. According to the land use survey for Jiangsu and Zhejiang provinces, since 1956, the mean annual reduction rate of arable land has been 0.4% in Jiangsu and 0.45% in Zhejiang. In Shanghai, from 1950 to 1980, the average annual reduction rate of arable land was 0.28%. The rate reached 0.82% from 1980 to 1984, 0.96% from 1985 to 1989, and more than 1% after 1990. Accordingly, the annual growth rate of grain production in the region was 2.65% in 1981-85, 0.9% in 1986-90 and even negative in 1991-1992. And the percentage of agriculture in the total production has declined year by year. Arable land has reduced by 8.7% in Yangji Township, a suburb of Wuxi City. As a result, food import has become import in most area of the region. It was the richest land, flowing with milk and honey, in China for the 2000 years.

With rapid economic development, many environmental and ecological problems have appeared in this region. According to the statistical survey of 48 small towns around the Taihu Lake watershed, the total annual amount of pollutant discharge was 3.7×10^8 t/a, of which industrial wastewater discharge occupied 90% and domestic sewage discharge occupied 10%. The water quality of Taihu Lake has been decreased by one grade every 10 years since the 1970s, with 80% of the industrial wastewater being discharged directly into the lake without any treatment. In 1992, more than 50% of the water in the lakes of Dianshan, Yangcheng and Gehu can not meet the national water standard of grade III. In Taihu Lake, the ratio was 32% in 1992, but in 1995, 70% of the Taihu water could not meet the national standard of grade III. The sewage treatment rate in these small towns is very low. For example, in 1985, the pollution survey in 12 cities and counties showed that the treatment rate of wastewater was only 11.7% and the percentage of the treated wastewater meeting the state environmental standard was only 1.8%. The order of industries in terms of the amount of discharged pollutants from large to small is chemical, textile, paper manufacture, food processing, tanning and plating. In 1989, the total amount of pollution discharge in Zhengjiang, Changzhou, Wuxi and Suzhou was 5.9×10^8 t/a. For example, Suzhou city has a population of 913.2 thousand and the amount of sewage was 1.72×10^7 t/a and COD 768.2 t/a, BOD 1594.4 t/a. The main pollutants of sewage were N, P, S and other organic matter. The municipal treatment capacity of municipal solid wastes (MSW) in the region was very low, most of which was dumped directly in the suburbs in many towns and cities. In Shanghai, the annual MSW in 1990 was 278.60 million tons, 372.03 million tons in 1995, and 453.84 million tons in 1997.

Due to the over-exploitation of groundwater and deforestation, the land of this region has degraded. The ground subsidence caused by over-exploitation of groundwater in the region was about 8,000 km^2. In Shanghai, Suzhou, Wuxi, Changzhou, Jiaxin, Huzhou, Ningbo and Shaoxin cities, the over-exploitation of groundwater has caused a serious falling in the water table level. In Suzhou-Wuxi-Changzhou area, the daily amount of groundwater usage is 1.1×10^6 m^3, so landfalls frequently take place. In Shanghai, from 1949 to 1963, the extraction of the groundwater usage went up from 0.9×10^8 m^3 to 2×10^8 m^3, and the annual landfall changed from 3.5 cm to 11.0 cm. According to the remote sensing survey of Hangzhou, Huzhou, Shaoxin and Ningbo cities, the soil erosion of the upper reach of the Chao-e-Jiang River is 8.0×10^5 t/a, an increase of 260% compared with that during 1958 -1963.

2.2 Situation of Jiangyin City

Jiangyin city is located in corridor of Suzhou-Wuxi-Changzhou, the southern part of Jiangsu province, China. It is situated at the north end of Taihu plain on the south bank of the Yangtze River, with Changshu city and Zhangjiagang city on the east, Wuxi county on the south, Wujing county and Changzhou city on the west, Jingjiang county in the north across the Yangtze River. It is an important traffic hub connecting the north and the south of China with a nice river port towards the East China Sea.

The city's total administrative area is 983 km^2. The longest distance from east to west is 58.5 km and 31 km from north to south. 87.1% of the land is terrestrial area, about 865.4 km^2; 12.9% is water surface, about 126.6 km^2, of which 57.5 km^2 is water of the Yangtze River. The bank length of deep water along the Yangtze River is 35 km. There are 768.7 thousand mu of cultivated land area (15 Chinese mu = 1 hectare), including 680.3 thousand mu of paddy field and 88.4 thousand mu of dry land. The cultivated land per capita is 0.70 mu. The total population of the city is 1.14 million. The density of population is 1127 persons/ km^2.

The north part of Jiangyin belongs to the alluvial plain of the Yangtze River, while the south belongs to the plain of Taihu. Its center is slightly higher than the surroundings. Its landform can be divided into three groups: the plain 542 km^2, 6.5-8.0 m high; the lower areas, 190 km^2, scattered along the Wuxi- Jiangyin Canal, the height of which is below 4.8 m; and the highland area 111 km^2, scattered in the north and central part. The proportion of the three landforms is 5:2:1. Jiangyin is located in the subtropical monsoon climate zone, with four distinctive seasons, sufficient sunshine and plentiful rainfall. The average temperature is 15.2 °C annually, 2.5 °C in Jan., 27.7 °C in July, the extreme highest 40.0 °C and the extreme lowest 14.2 °C. The annual sunshine duration is 2092.6 hours. The annual average non-frost duration is 226 days, 337 days above 0 °C. The annual average rainfall is 1045.4 mm. There is a continuate rain called "plum rain" in the area, which usually lasts 23 days. There are nearly 3000 multifarious rivers, 12 of which flow down the Yangtze River and 16 of which are east-west connection rivers. The density of river network is 4.98 km/ km^2.

Jiangyin is an old city with a very long history of more than 2000 years. Before 1949, the economy of Jiangyin developed very slowly. After liberation, led by the Chinese Communist Party, the people of Jiangyin have worked hard for around 50 years, have overcome many unbelievable difficulties and made great achievements in the whole society and economic development. The period from 1949 to 1978 can be roughly divided into two different phases.

From 1949 to 1957, it was the People's Republic of China's beginning period. In nine years, the economy recovered and began initial development. The yearly average growth rate of gross industrial and agricultural output value was 10.3%. In 1957, the gross industrial and agricultural output value was 245 million yuan, more than two times that of 1950. The yearly growth rate of financial revenue was 27.2%, with 23.02 million yuan in 1957.

From 1958 to 1977, the economic development made some achievements but also underwent many serious difficulties. It is in this phase that Dayuejin (Great Leap Forward) and Great Revolution of Culture occurred. The agricultural output cyccled up and down for 20 years. The yearly growth rate of gross agricultural output value was only 1.6%, from 133 million yuan in 1957 to 183 million yuan in 1977. Although the policy was "grain first", the yearly growth rate of the total yield of grain was only 2%, from 265 thousand tons in 1957 to 396 thousand tons in 1977. Industrial production was cyclic as well. The annual growth rate was 9.3% for 20 years. The gross industrial output value was 112 million yuan in 1957 and 667 million yuan in 1977. The yearly growth rate of total retail sales of consumer goods was 7.4%. The annual average growth rate of financial revenue was 7.1%.

Since 1978, Jiangyin City has been developing faster and faster. In agriculture, the total yield of grain in 1949 was 147.4 thousand tons, yearly 252.5 thousand tons in 1950s, 330.8 thousand tons in 1960s, 437.7 thousand tons in 1970s and 433.8 thousand tons in 1980s although the cultivated land area had decreased by 26 thousand mu. In 1949, the gross industrial output value for Jinagyin County was only 33.75 million yuan, and the work force less than 3000. In 1990, there were 3095 factories, founded by municipal government, town government and villages respectively, and 348.6 thousand workers in 1990. These factories produced more than 6000 kinds of production belonging to 90 groups. The gross industrial output value was 8.62 billion yuan, 90.73% of the gross industrial and agricultural output value. The ratio of light industrial value to heavy industrial value was 52.3:47.7.

Table 1 Personal Income and GNP in Yangtze River Delta, 1995

City	Urban' Income per capita (RMB yuan)	Rural income per capita (RMB yuan)	The composition of GNP (%)		
			Primary Industry	Secondary Industry	Tertiary Industry
Shanhai	6822	4246	2.5	57.3	40.2
Hangzhou	6096	2712	9.1	53.8	37.1
Wuxi	5324	3976	5.3	59.6	35.1
Nanjing	4658	2471	7.6	52.2	40.2
Shuzhou	5450	3756	8.9	60.2	30.9
Changzhou	5231	3397	10.8	59.7	29.5
Jiaxin	6203	3248	17.7	57.5	24.8
Zhengjiang	4764	2879	11.8	46.0	31.6
Nantong	4923	2547	23.2	50.2	26.6
Yangzhou	5003	2310	16.8	55.9	27.3
Huzhou	5961	3052	18.7	52.0	29.3
Ningbo	6804	3350	13.4	56.4	30.2
Shaoxin	6025	3183	13.9	59.9	26.2
Zhoushan	6202	3592	30.3	33.8	35.9
Delta Mean	6308	3086	9.5	57.3	33.2
Country Mean	3892.9	1577.7	20.6	48.4	31.0

Source: The Water-land Resources and Regional Development in Yangtze River Delta She Zi-xiang

During the past two decades, its annual growth rate of GDP was 23.7%, and the economy increased totally by 56 times. Non-agricultural population increased by 4 times. Rural industry accounts for 86% of the total industry. The old town expanded, new areas developed, rural areas urbanized, and a large amount of infrastructure was constructed.

Table 2 Daily Eco-flow in Jiangyin city

	Unit	1986	1997
Revenue	10^4 yuan	71	357
GDP	10^4 yuan	1646	19876
Retail sales	10^4 yuan	162	1664
Passenger transportation	10^4 person	0.65	3.52
Cargo transportation	10^4 tons	2.55	2.50
Birth	person	45	28
Death	person	19	21
Net increase	person	+26	+9

Source: `98 Statistical Yearbook of Wuxi

Table 3 Town-and Village Enterprises (TVE) in Jiangyin
(10,000 RMB Yuan, 1990 price)

Year	Industrial product	Product value of TVE	Proportion of TVE product value in total industrial product value(%)
1986	562971	387914	68.90
1988	915699	665698	72.70
1990	1066743	798285	74.83
1992	1766930	1386352	78.46
1994	3488760	2919965	83.70
1996	5205907	4465521	85.78

Source: `98 Statistical Yearbook of Wuxi

Table 4 Industrial structure in Jiangyin
(100 million RMB yuan)

Year	Gross Domestic Product	Tertiary industry	Proportion of tertiary industry in GDP(%)
1978	4.33	0.81	18.71
1980	6.22	1.14	18.33
1985	16.67	2.41	14.46
1988	31.13	5.03	16.16
1990	36.69	6.25	17.03
1992	78.05	18.96	24.30
1995	203.16	69.19	34.06
1997	245.03	83.81	34.20

Source: Statistical Yearbook of Wuxi (1998).

Table 5 DPSER model of Jiangyin (1950-2010)

	Phase I (1950 – 1965) Economy Recovery	**Phase II (1966 -1978) Economy Stagnancy**	**Phase III (1979-1991) Economy Transformation**	**Phase IV (1992-1996) Economy Acceleration**	**Phase V (1997-2010) Economy Stabilizing**
Driving force	Establishment of P.R.China Great leap and Peoples' commune	Cultural revolution Dazhai model of "man conquering nature"	Institutional reform from planed economy to market economy	More open policy emphasized by Mr. Deng	Financial crisis of South-east Asia, huge amount of infrastructure investment
Pressure	Initiation of industrialization	Shortage of city supply Urban infrastructure and housing shortage Social conflicts	Rapid TVE especially heavy industry, Employment of returned residents from countryside	Large scale development and infrastructure construction, Sprawling of urban area, rapid small town development	Global change Institutional reform of SOE and TVE Strict env. legislation Implementing ISO 14000
State	Nice social order Low productivity High employment	Wetland exploitation Small industry development	Regional water and air pollution, ecosystem deterioration, city life improvement	Municipal water, air, noise and solid wastes pollution, cropland loss, low eco-awareness	Environment quality meets the national standard, Ecosystem restored
Effect	Deforestation Soil erosion	Increasing natural disaster, biodiversity loss, poor urban infrastructure, stable urban development	Deforestation, acid rain, pollution accidents and complains, improving human wellbeing	Eutrophication, Disease, Landscape disintegration, Eco-service weakening, Human eco-deterioration	Eco-industry Ecopolis and Eco-culture demonstration
Response	City greening, Citizen registration system, Residents migration to rural area	Student migration to countryside, strict urban population control, family planning	Upgrading Jiangyin county into city, Pollution control and end-pipe treatment, EIA	Sewage treatment plant, Environment legislation and regulation, Cleaner technology, Local agenda 21	Technological innovation, Institutional reform, Behavioral inducement

3. Driving Force: Region Urbanization & Industrialization

It is urgent for Chinese people to realize the need for the modernization of China. Urbanization and industrialization is the internal driving force for the development of China. Because of urbanization and industrialization, the Yangtze River Delta has become one of the most rapidly urbanizing and rural industrializing areas in China. Its annual growth rate of GDP is 50% higher than that of China's average since 1992. The total population has reached 73.71 million, of which 22.87 million was urban population (1993). City population in the region has increased by 60% and population in small towns has increased by 2.7 times and around 8 million labors have immigrated to this region during the past two decades. The annual growth rate of GDP is 12.7%, farmers' income has increased by 19 times, annually 17.4%, citizens' has income increased by 17 times, annually 16.4%, urbanized has area increased by 17.57%, and the traffic area has increased by 46.67%. Now the Yangtze River Delta is a very important region in China, and plays a crucial role in the national economy. Its area, population, GDP and revenue are 1.04%, 6.09%, 15.42% and 21.8% of the total for China respectively. In this region, all the industries, including primary industry, secondary industry and tertiary industry, developed fast in a period of only 20 years. In 1992, the total industrial output value was 74.53 billion RMB yuan, 20% of that of China. The ratio among the primary, secondary and tertiary industry is 9.5%: 57%: 33.2%, while their labor ratio is 30:45:25. In large cities such as Shanghai, Suzhou, Wuxi, Changzhou, Nanjing, Hangzhou, Zhengjiang, Ningbo, Shaoxin and Zhoushan, the tertiary industry is stronger than the primary industry, while in Yangzhou, Nantong, Jiaxin and Huzhou, the primary industry overwhelms the tertiary industry. In towns and rural areas, the rural industry growth is much faster than that of cities so that the average income per capita of the region is nearly twice as much as that of China. In the agricultural structure, the output of farming, forestry, animal husbandry, fishery and agro-processing products accounts for 48%, 2%, 28%, 14% and 8% respectively.

Jiangyin is an outstanding model for the south of Jiangsu. Great changes took place in Jiangyin City during the past 11-year period from 1986 to 1997, which can be proved by the contrast of some index changes during one day (Table 2, price as that in those year).

In agriculture, the model of singly developing agricultural economy has been adjusted, moving to the developmental orbit in which agriculture• forestry• fishery, and so on, develop coordinately, and while, industry, commerce, transport, building and services also develop fast. The average annual growth rate of agricultural output value amounted to 5% between 1979 and 1988, and the proportion of plantation in agriculture decreased to 45% in 1988 from 79% in 1978. Agriculture benefits have increased yearly. The annual output per peasant amounted to 2,220 yuan in 1988, which is 2 times as much as that in 1978 whereas the total income of agricultural economy increased to 7.37 billion yuan in 1988 from 0.53 billion yuan in 1978. A lot of labourers were transferred from agriculture to industrial and service enterprises. In 1990, 66% of agricultural laborers entered industrial and service trades.

In 1996, the output values of primary industry increased by 1.334 billion yuan, i.e. increased by 16.3% than that in 1995, which accounted for 6.01% of Jiangying's GNP. The grain yield also increased. The total grain yields amounted to 4.58 million tons. At the same time, the pork and poultry yields increased by 9.6% and 20.46% respectively.

Since the end of the 1970s, with large-scale expansion and structure adjustment, much progress has been gained by industrial enterprises in Jiangyin City. So far, an industrial system based on light and textile industries, machinery and electricity power industries, and metallurgical industry has been established, which together produce more than ninety different kinds of products.

In Jiangyin City, another prominent characteristic is the development of town and village enterprises. Since the 1970s, town and village enterprises in Jiangyin City have been developing fast and well. The output values of high quality products amounted to 51 million yuan in 1988. More than two hundreds different kinds of products have entered the international markets.

By the end of 1996, there were 4,090 industrial enterprises in Jiangyin City, which employed 297,634 workers and owned 19.7 billion yuan in fixed assets. The total assets amounted to 40.521 billion yuan. In 1996, the secondary industry output values increased by 13.264 billion yuan, i.e. by 13.74%, which accounted for 59.74% of GDP of Jiangyin. The total industrial output values increased by 21.22%, 57.982 billion yuan.

Since 1978, the tertiary industry in Jiangyin has been developing quickly. In 1996, the output value of the tertiary industry amounted to 7.6 billion yuan, an increased of 7.43%. The gross output values accounted for 34.25% of Jiangyin's GDP.

4. Pressure: Environmental Pollutants Discharge

In recent years, the amount of pollutants discharged increased greatly due to rapid urbanization and industrialization in the Yangtze Delta. These pollutants have exerted considerable pressure on the environment and have caused a large number of problems. Comparison among the cities of South Jiangsu, the situation changes in different city. In the three county level cities in the Wuxi region, in 1997, wastewater discharged in Xishan is the most, 80.74 million ton, industrial waste gas and dust emitted in Yixin is the most, 383.65×10^8 m^3 and 12769 ton respectively, and in Jiangyin, the situation was in the middle and not the worst.

Table 6 Discharge and comprehensive use of industrial pollutants in Jiangyin, Yixin and Xishan, 1997

Items	unit	Jiangyin	Yixin	Xishan
1. Industrial wastewater discharged	10^4 tons	7049	2100	8074
Industrial wastewater reaching discharged standards	10^4 tons	5294	1112	6133
2. Iindustrial waste gas discharged	$10^8.m^3$	286.77	383.65	126.44
Waste gas discharged from fuel	$10^8.m^3$	279.28	152.15	126.3
Soot and dust removed	$10^8.m^3$	274.83	82.01	120.72
Waste gas discharged in the process of production	$10^8.m^3$	7.49	231.5	0.14
Gas purified	$10^8.m^3$	5.4	212.11	0.09

Sulfur discharged with waste gas	ton	46749	35942	18933
soot discharged	ton	22539	17576	4435
3.industrial dust discharged	ton	4456	12769	5170
Industrial dust retrieved	ton	6010	40768	10560
4.industrial waste residue produced	10^4 tons	77.88	24.16	36.71
Industrial waste residue used	10^4 tons	75.86	21.46	30.34
Industrial waste residue treatment	10^4 tons	1.01	0.55	1.4
Industrial waste residue discharged	10^4 tons	0.26		1.53
Volume of waste residue accumulated over years	10^4 tons	108.33	24.5	0.07
Area occupied by waste residue	10^4 m^2	17.01	0.03	0.03

Source: `98 statistical yearbook of Wuxi

In Suzhou-Wuxi-Changzhou corridor, the situation in Suzhou was the worst, and its wastewater, waste gas, SO_2 and soot discharged was the most. Changzhou was the best and Wuxi was medium.

Three cities, Xishan, Jiangyin, Changshu, discharged most industrial wastewater. Wujin was in first position for emission of industrial waste gases. The champion, runner-up, and bronze medallist for emitting sulfur dioxide were Changshu, Jiangyin, and Zhangjiagang respectively, and the same three cities emitted most soot, but the order altered to first, Jiangyin, second, Changshu, and Zhangjiagang, third. Considering industrial dust emission, Kunshan and Wujiang were the number one and number two respectively.

Table 7 Three Industrial wastes discharge and disposal of Jiangsu, 1997

Cities	Jiangyin	Xishan	Wujin	Changshu	Zhangjiagang	Kunshan	Wujiang	Taicang
Industrial Wastewater Discharge (10^4.t)	7049	8074	2408	6480	4026	2606	5427	1591
Industrial Wastewater Disposal (10^4t)			1133	3529	1178	963	1860	1190
Industrial Waste Gases Emission (10^8 m^3)	286.77	126.44	57189 6	332	171	62	77	56
Sulfur Dioxide Emission (t)	46749	18933	12917	68283	28725	16075	20067	13271
Sulfur Dioxide Removed (t)				1346	2594	1817	106	115
Soot Emission (t)	22539	4435	4192	14953	10882	6764	7440	4149
Soot Removed (t)				401101	40807	13203	21215	10195
Industrial Dust Emission (t)	4456	5170	4671	2321	4421	11005	6236	1858
Industrial Dust Recovery (t)	6010	10560	2822	9207	20299	3095	16300	8748
Industrial Solid Waste Discharge (10^4 t)	0.26	1.53				0.03		0.01
Industrial Solid Waste Disposal (10^4 t)	1.01	1.40		0.72	1.58	0.07		0.88
Noise Attainment Area (km^2)				17	7.8	6.6	2.9	4.5

Source: `98 Statistical Yearbook of Jiangsu

In 1997, for Jiangyin, compared with that in 1985, the total amount of waste gases discharged increased 5.37 times and the waste gas originating from fuel combustion increased 10.2 times, but the waste gas from industrial production decreased 62.6%. In 1997, the total amount of waste gases was 14.6% more than that in 1994, from fuel combustion, 14.4% more, and the waste gas from industrial production, 23.3% more. In 1997, the total amount of SO_2 emitted was 1.06 times higher than that in 1987, but 4.57% less than that in 1994. On the other hand, the amount of SO_2 from industrial sources increased by 37.2% in the period between 1994 and 1997. The amount of industrial wastewater expelled increased by 1.74 times from 1985 to 1997, but fortunately decreased 92.3% in the period between 1994 and 1997. The amount of solid waste generated by industrial procedure increased about 6.95 times from 1985 to 1997, and 13.1 times from 1994 to 1997. Due to comprehensively using these solid wastes, the amount of solid waste expelled went down 88% and 99.7% respectively, compared with that in 1985 and in 1994.

In different industrial sections, the amount of pollutants discharged is different. In 1998, according to industrial output value, textile, electric equipment and machinery, raw chemical material and chemical production and smelting and pressing of ferrous metal are the main economic player. In terms of the amount of sulfur dioxide, the section of electric power and gas production occupied first position, with 74.9% of the total, then smelting and pressing of ferrous metal followed by textiles, their rates are 11.1% and 6.2% respectively. For wastewater, smelting and pressing of ferrous metal, textile and the raw chemical material and chemical production industries were number one, two and three. Their amount of discharge compared to the total were 35.7%, 30.8% and 18.9% respectively.

In 1988, the total wastewater discharge in Jiangsu was 29.18×10^8 t, which was discharged directly into the surrounding water environment without any treatment polluting the water. According to water quality data, the distribution of pollutant concentrations regularly formed plane or linear zone of pollution downstream. The polluted central part was cities, where pollution was the most severe.

The rate of industrial three wastes disposed in Jiangyin was the lowest among the cities listed (table 7). The rate of wastewater treated in Wujin City was 47.05%, 54.46% in Changshu, 29.26% in Zhanjiagang, 36.95% in Kunshan, 34.27% in Wushan and 74.80% in Taicang, but for Jiangyin, there are no statistics. Other items, such as industrial waste gases, sulfur dioxide, industrial dust and soot and industrial solid waste, were the same condition as the rate of wastewater treated.

The pollution of the rivers in Jiangyin was primarily caused by organic pollutants and the situation has become more and more severe. The rate of the out-of-standard of DO in 1995 was 4.5 times more than that in 1986, chemical oxygen demands, 2.59 times and ammonia nitrogen, 1.13 times. Chengyun River in Wuxi, relative to Jiangyin, was polluted more seriously. Chemical oxygen demand doubled and redoubled annually.

Atmospheric pollution in Jiangsu is due to coal smog pollution. Major pollutants are sulfur dioxide, TSP and dust-fall. Fluoride is another major atmospheric pollutant in the rural area. Acid precipitation occurs frequently due to the severe atmospheric pollution. In 1988, 33 counties in Jiangsu Province, 80.5% of the counties monitored, had acid precipitation. In cities, sulfur dioxide was controlled to a certain degree with the construction of the coal gas project and central heating systems. However, the rural area suffering from sulfur dioxide pollution enlarged rapidly with the development of rural industrialization and the construction of a town.

5. State: Environmental Quality

The environmental quality in the Yangtze Delta has changed since the 1980s. This is the result of pollution caused by the discharge of pollutants and the deterioration of the ecosystem. In South Jiangsu, the environmental state is illustrated by environmental quality in this chapter and the ecosystemic state is represented by the situation of soil in the next chapter.

The water quality in South Jiangsu can be illustrated by the water of Jiangyin, Yixin and Xishan. Among the three cities, water bodies pollution in Yixin was not very stern relatively, mainly in grade I-III. For Jiangyin, the pollution was quite serious, most of water bodies in grade III, mainly in grade IV, although the situation was middle among the three cities.

In Wuxi region, the leading pollutants in Wuxi were BOD, permanaganate index, volatile phenol, COD, and ammonia nitrogen. Among these pollutants, the rate of out-of-standard for ammonia nitrogen has been 100% since 1990, the rate of out-of-standard of COD has been increasing and the rate of out-of-standard of DO went up-and-down. In Suzhou-Wuxi-Changzhou corridor, the groundwater contaminated was due to industrial three wastes discharged, the excessive use of pesticide and chemical fertilizer, and the leakage of polluted surface water. The leading pollutants were "three nitrogen"(NH_3-N, NO_2- -N and NO_3- -N) and organic pollutants. The quality of groundwater degraded year by year. The concentration of Cl^-, Ca^{++}, CO_3^{2-} and hardness increased greatly. Meanwhile, the content of dissociative CO_2 went down and the content of ammonia nitrogen, nitrite nitrogen and total ferrum exceeded standards to some extent. In 1994, the highest concentration of nitrite nitrogen obtained in Xishan was 4.0 mg/L, 61.5 times higher than the standard. The rate of out-of-standard of total ferrum in the Suzhou centric area and Wuxian were 62.5% and 42.8% respectively.

In the Yangtze River Delta, the main major rivers and lakes have been contaminated. According to a survey in Jiangsu, 62% of the reaches were polluted, at which the water quality was Grade III or worse, and about 25% of the reaches were contaminated seriously in 1985. In Shanghai, the water quality at 67.9% of the reaches was worse than Grade III, among which, the Suzhou River was the worst, 100% polluted and about 50% smelly and black all the year. Since the 1980's, the area meeting Grade II in Taihu Lake has shrunk from 69% to 15%, the area meeting Grade III increased, from 30% to 70%, and the area meeting Grade IV has enlarged, from 1% to 14%. In a decade, the total water quality in Taihu Lake has degraded a rank. At present, Wulihu Lake and Meilianghu Lake, belonging to Taihu Lake, can not be used as a source for tap water. In 1992, 52.1% of the total area of Dianshanhu Lake, which could meet the limits stipulated by Grade II before the 1980s, reached Grade III, with 47.9% at Grade IV, so the situation was very serious. Eutrophication in the lakes developed rapidly due to excessive nitrogen and phosphates entering the lakes. In recent years, the concentration of nitrogen and phosphate has been rising greatly in Taihu Lake and eutrophication is obvious. In 1981, the eutrophication indexes for Taihu Lake were chl.a 4.0 mg / m^3, TN 0.98 mg / L, TP 0.02 mg / L and SD 0.8 m, and in 1991, these indexes were chl.a 12 mg / m^3, TN 1.89 mg / L, TP 0.058 mg / L and SD 0.4 m, respectively. Because of eutrophication, water bloom broke out with high frequency in recent years.

While industrialization and urbanization in Jiangyin developed rapidly in recent years, the atmospheric environmental quality did not changed drastically. All the concentrations of pollutants monitored can meet the demands of grade II according to National Ambient Air Standard. Leading atmospheric pollutants are SO_2, TSP and dust-fall due to coal smog pollution.

Water quality has become worse and worse since 1990. In the 1980's, the concentrations of water pollutants at some reaches met the limits stipulated in grade III of National Water Environmental Standard. In 1990, the water quality in all the reaches in Jinagyin was worse than grade III. At major reaches, the concentrations of pollutants have exceeded the limits stipulated by grade IV since 1994, and some are worse than grade V. The primary pollutants are organic materials, NH_3-N, P and oil. In urban areas, the water pollution is due to industrial wastewater and domestic wastewater. From 1986 to 1989, the rate of out-of-standard increased step by step, for DO from 11.1% to 24.2% and COD from 25.9% to 45.8%. The rate of out-of-standard of ammonia nitrogen was very high, with 88.6% in 1986. Water quality in the reaches of Xicheng Canal in Jiangyin was worse than Grade III, with the situation at Sihe Bridge being the worst. The leading pollutants were BOD and volatile phenol.

Table.8 Grade of River Water Quality in Three Cities of Wuxi

City	River	Cross Section	Oxygen Dissolved	Permanganate Index	Biochemical Oxygen Demand	Volatile Phenol
Jiangyin	Xicheng Canal	Huangtiangang Bridge	•	•	•	•
	Xicheng Canal	Coal mine machinery factory	•	•	•	•
	Xicheng Canal	Yuecheng Bridge	•	•	•	•
	Xicheng Canal	Sihe Bridge	•	•	•	•
Xishan	Xibei Canal	Zhangtang Bridge	•	•	•	•
	Zhihugang	Yangjia Village	•	•	•	•
	Zhihugang	Yangshan Bridge	•	•	•	•
	Xicheng Canal	Beiyu Bridge	•	•	•	•
	Yangxi River	Outang Bridge	•	•	•	•
Yixin	Dongjiu River	Dongjiu	•	•	•	•
	Xijiu River	Xijiu	•	•	•	•
	Nanxi River	Pangjiaba	•	•	•	•

Source: Environmental Quality Report of Jiangyin

6. State: Impacts on Soil Resource with Urbanization and Industrialization

Soil is a kind of important resource that is tied to the sustainable development of a region. A great change in the land use pattern took place with the development of regional urbanization and rural industrialization. In Jiangyin, compared with that in 1978, arable land has decreased by 3.44×10^3 ha in 1997, 6.47% of the arable land of 1978. On average, arable land has decreased by 172 ha yearly. The exhaustion period of the ploughed resource was 248.8 years if we regard the arable land in 1997 as the base and assumed that arable land reduced at this rate.

In Suzhou, Wuxi and Changzhou, the situation was the same as that in Jiangyin. In 1985, the arable land of Suzhou was 36.8×10^4 hm^2, and in 1992, 35×10^4 hm^2, decreasing by 1.8×10^4 hm^2, by 4.9%, in a period of 7 years. In the same period, the arable land of Wuxi decreased 7433 hm^2, reducing by 3.9%, and in Changzhou, 2390 hm^2, and 1.2%.

The factors influencing sustainable use of land include land waste, soil fertility reduction and soil degradation. According to an investigation, the total decrease of arable land from 1985 to 1987 in Jiangsu Province was 5.82×10^4 hm^2, 46.21% of which was occupied by town and village enterprises. In 1988, all the town and village enterprises in Jiangsu took 6.3×10^4 hm^2 land, 0.62% of the total area of Jiangsu, and 1.37% of the total arable land. But the area occupied by the buildings in town and village enterprises was 1.18×10^4 hm^2, the density of building only 18.73%, and another 5.14×10^4 hm^2 was not used effectively or unused. There were about 3.7×10^4 hm^2 deserted land in Jiangsu due to construction projects. Thus land waste and deserted land is very serious. Total area of soil and water loss in Jiangsu was 144.91×10^4 hm^2. The area of soil and water loss in the hills area was 91.6×10^4 hm^2, which is over half of the total area of the hills area. In the plain area, the area of soil and water loss was 53.29×10^4 hm^2, which was mainly sandy soil areas of the plain area. The amount of soil erosion in the hills area was 1714×10^4 t each year, on average, 1900 t/km^2. In the sandy soil areas of the plain area, the amount of soil loss from the banks of streams and ditches usually was 1500 t/km^2 every year, with over 1×10^4 t/km^2 in the worst area. After the 1970's, the usage of chemical fertilizer increased progressively. The amount of usage of chemical fertilizers in Jiangsu increased by 87.7%, from 118.1×10^4 t in 1980 to 221.70×10^4 t in 1990. Meanwhile, the production of green manure decreased over 78%, from 102.6×10^4 hm^2 in 1980 to 23.44×10^4 hm^2 in 1990, and mud of weed pool decreased over 80%, from about 5000×10^4 t annually in the 1970's to 1000×10^4 t in recent years. The use of barnyard manure reduced from 60% to 40%. The change of types of fertilizers resulted in the change of soil, including four aspects: organic substances imported and exported unequally, the supply nitrogen unsustainable, other elements, such as phosphate and potassium, supplied inadequately, and ruination of the soil structure. In 1988, 18.88% of arable land in Jiangsu was polluted by three industrial wastes. 72.6% of the polluted arable land was due to wastewater pollution, 27.2% due to waste gases and 0.2% due to solid waste. The usage of chemical fertilizers and pesticides in rural areas increased year by year, but the usage of these chemical fertilizers and pesticides was not scientifically applied. The usage of chemical fertilizers and pesticides in Jiangyin was 14.7% and 22.3% more respectively than that in Xishan and Yixin.

Table 9 Usage of Chemical Fertilizer in Three Cities of Wuxi, 1997

	Nitrogen Fertilizer		Phosphate Fertilizer		Potassium Fertilizer		Mixed Fertilizer		Total
	T	Kg/Mu	T	Kg/Mu	T	Kg/Mu	T	Kg/Mu	Kg/Mu
Jiangyin	20093	31.2	1369	2.1	562	0.8	3679	5.6	39.7
Xishan	22783	27.2	839	1.0	1090	1.3	5776	6.8	36.3
Yixin	28969	25.5	2691	2.6	1334	1.2	3208	2.8	32.1

Source: '98 Statistical Yearbook of Wuxi

7. Effect: Assessment of the Regional Urbanization & Industrialization

The whole social appearance in South Jiangsu has changed because of urbanization and industrialization. The effect of urbanization and industrialization is profound so that it is necessary to assess these effects. The urbanization of South Jiangsu was characterized by the concentration of population and non-agricultural industry around the original small towns. During the decade from 1980 to 1990, the total population of South Jiangsu increased at the rate of 0.90%, and the level of urbanization was raised from 20.7% to 26.19%. Among all the cities of the region, the population of center cities, such as Suzhou, Wuxi, and Changzhou, went up by 2.66% annually, and that of organic towns went up by 5.07%. It was thus clear that the growth of population was slower in cities than that in towns. The growth of town population was mainly due to a change of administrative structure. The number of the organic towns in South Jiangsu grew from 33 to 144 in ten years, and the population of these new towns made up 80% of the whole population growth. General speaking, four parts composed the dynamic growth of population in small towns; the inhabitants including those registered and unregistered, commuting population taking on non-agriculture activities in towns during daylight and turning back to their home villages at night, temporary residents, and floating people. The former two are the main constituents. In 1990, a survey showed that the commuting people made up 35% of the small towns of Wuxi City, many of whom had strong economic power and had developed township and village enterprises, and the number of commuting people greatly exceeded that of the inhabitants.

The construction of industrial districts promoted the concentration of production in the countryside, and became the basis of urbanization. Now all counties in South Jiangsu have their own developing districts, and 70% of villages and towns have built industrial districts.

In the same period, great changes also took place in the structure of the labor force. Small towns in South of Jiangsu were mainly industrial and the proportion of the tertiary industry was very low. Statistics suggested that all or almost all labor coming from primary industry transfer to tertiary industry and secondary industry in the same proportion.

Table 10 Labors changes in South Jiangsu

(10, 000 persons)

	1989		1993		Increase rate of 1993 relative to 1989 (%)	
	South Jiangsu	Within County (city)*	South Jiangsu	Within County (city)*	South Jiangsu	Within County (city)*
Social labors	781.75	628.19	785.21	629.92	+0.44	+0.28
Primary industry	225.71	219.9	206.29	200.69	-8.60	-8.74
Secondary industry	408.87	306.19	408.71	308.51	-0.04	+0.76
Tertiary industry	147.17	102.1	170.21	120.51	+15.66	+18.03

*within county (city): other counties (cities) other than Suzhou, Wuxi, and Changzhou.
Source: `95 Statistical Yearbook of Jiangsu

In Jiangyin, there were 984.8 thousand people in 1978, and the level of urbanization only reached 8.19%. But in 1997, urbanization had reached 28.7%, and the non-agricultural population had increased to 377.9 thousand.

Table 11 Population dynamics of Jiangyin city

Year	Total population	Non-agriculture population	Urbanization rate(%)
1978	98.48	8.05	8.17
1980	99.96	9.38	17.56
1982	101.92	10.77	10.57
1985	102.65	11.45	11.15
1988	106.73	13.79	24.07
1990	110.30	14.98	13.58
1992	112.27	23.90	21.29
1995	113.72	31.84	28.00
1997	114.26	32.79	28.70

Source: `98 Statistical Yearbook of Wuxi

There are two main methods by which the population of Jiangyin has increased. One is associated with the nature of the urban population and the movement of villagers within the region; the other is due to immigration from outside this region.

Since the natural growth rate has kept at 5‰ in recent years, the normal population increase has been mainly due to the migration of villagers to towns, which produce a commuting population approaching 80 thousand in the town and township areas, most of whom often live in the township area, while few live in the downtown area. This incomplete gathering clearly shows the "Model of South Jiangsu" in the process of urbanization, which is characterized with the principle of "leaving within the native place and setting in the neighbor land."

Abnormal population gathering is referred to the gathering of immigrants. There had been 57.5 thousand immigrant laborers by the end of 1995, 54.2% of whom came from the outside of Jiangsu province, and 29.3% of whom came from the less advanced areas within the province. and 16.7% of laborers within cities were floating people. Of all the immigrants, 24.7% moved to cities and 75.3% dispersed in villages and towns, where township and village enterprises became the key to absorbing immigrant laborers.

There was polarizing trend of the gathering of population and industry. Township and village enterprises were the main source of the acceptance of immigrant laborers.

Population concnetration was the major trend, but some dispersal exists at the same time although the dispersal of urban population is weak, and the gathering is strong. The density of population dispersal decreased with distance. The proportion of emigrant of the urban area was 60.7%, that outside the urban area but within the province was 25.9%, and that outside the province was 13.4%.

On the whole, there are several problems with the pattern of population change. First, Urbanization lagged behind non-agriculturialization. After 1985, although urbanization was sped up, it is not the result of non-agriculturization and didn't lead to the gather of population in urban area. Second, the migration legged behind so that the scale of town population was small. Third, the degree of centralization of urban districts was so low that the attraction of urban districts was insufficient. Urban region has not played a dominant role in the process of urbanization in the past ten years.

In Suzhou-Wuxi-Changzhou region, by the end of 1992 there were 237 central towns, 89 more than that in 1987. When the center towns grew, the scale and the inner quality of other towns changed a lot. There were 587 small towns in South Jiangsu, averagely one per 30 km^2. Big towns whose population surpassed 20 thousand, some even more than 50 thousand, appeared suddenly. Small towns became the center of township and village enterprises' development. Township and village enterprises are the direct cause for the flourishing of small town. In 1992, there were 11,717 rural enterprises in Su-Xi-Chang region, whose output value was 97.482 billion yuan, on average 27 in each town with an output value of 227 million yuan. These enterprises employed 1.80 million workers. More than 2.00 million immigrants worked in these towns. One of the most outstanding characteristics of the change in land-use pattern was the increase in the number of small towns and the expansion of the municipal area.

Some county towns will be upgraded to medium-sized cities. In some towns, the population only was 10 to 50 thousand in the end of the 70s, but now, there are 100 thousand or more people due to the development in more than ten years. It is sure that some center towns will grow into small cities. The newly constructed small towns will be the largest group of South Jiangsu with on average scale of 100 thousand people encompassing over 40 % of the whole population of county and town.

Not all the villages developed at the same rate and got the same wealthy level. Among these villages, some villages with developed industries will rise up to communities by focusing on industry. This trend results in the formation of the urban system in which large cities are the nuclei, medium and small cities are basis, and the towns, networks.

With the emigration of population, the expansion of land used by small towns, and the decline of population in villages, some villages will disappear or be incorporated into small towns or center villages.

Agriculture modernization has an influence on the improvement of urbanization. The first step is to enhance the level of mechanization. The second is to stimulate and strengthen the service system of agricultural socialization. The third is a break through in the management structure. At present many kinds of agricultural enterprises with a reasonable scale have appeared in South Jiangsu, and the areas run by these enterprises amounted to 60% or so in Wuxi City. With the development of urbanization, the suburbanization of agriculture is more obvious.

In 1990, the ratio of the gross national product of the primary, secondary and tertiary industry was 16 to 63 to 22, and the non-agricultural industry played absolutely a dominant role. In the social structure of laborers, 28.9% were in the primary industry, and over 50% were in the secondary industry. Now the non-agricultural industry is the major part of the economy of South Jiangsu. The workers in town and village enterprises make up about 30% to 80% of the total of South Jiangsu. The area occupied by these enterprises overpasses half of the industrial area.

Two features can be seen during the process of urbanization in Jiangyin City. One is the development of tertiary industry. The other is the growth of township and village enterprises. The output value of tertiary industry was very low in 1978, only 80 million yuan and 18.7% of GDP. In 1997, however, the value went up to 8.381 billion yuan, 100 times more than that in 1978, with 34.2% of GDP, almost twice as much. Therefore, we conclude that urbanization results in the fast development of tertiary industry. In this period, many township and village enterprises sprouted out and developed very fast. In 1986, the output value of TVEs in the city amounted to 3879 million yuan, making up 68.90% of the gross output value of the industry. Ten years later, in 1996, it amounted to 4466 million, and the ratio went up to 85.78%. Township and village enterprises played the leading role in urban industrial development.

The rate of development of the urbanizing land increased after the 1980s. In Suzhou City, the built up area in 1982 increased by 8.84 km^2 compared with that in 1957, gaining 46% in 25 years. In 1992, it was 34.38 km^2 more than that in 1982, amounting to 62.45km^2. The average rate of increase was 8% annually, at 7.4 times higher than that between1957-1982. In 1957, residential and public building land made up 80 %, but industrial land was only 8.5%. In 1982 industrial land was 30.3%, increasing by 21.8%, while residential and public building land dropped 21.8%. Changes have taken place in the pattern of land-use since the 1980s. In 1992, residential and public building land enlarged by 19.08 km^2 to 2.5 times as large as that of industrial land, and the tendency for residential and public building land decline absolutely and relatively in the former 25 years was reversed. Residential and public building land is the dominating factor affecting landuse pattern in the period, making up about 55.5% of the built up area. In 1992 the ratio of the traffic and urban road area in the total region increased from 7.4% in 1984 to 10.3%. The expansion and pattern succession of urban land is the comprehensive result of functional changes, population increase and other social economic changes.

The development of enterprises and industrial land was a leading factor in the expansion of urban land before the beginning of the 1980s. The built-up area of Suzhou increased by 8.74 km^2 in 1982 compared to the 1950s, among which the industrial land-use increased by 6.86 km^2, making up 78.6% of increment of constructive land-use. In the same period, industrial land increased by 11.89 km^2 in Wuxi, making up 45.02%.

Table 12 Land use in construction area in Suzhou

(unit:km^2)

Type of land use	1957		1963		1973		1983		1992	
	area	%	area	%	area	%	area	%	area	%
Total	19.229	100	19.410	100	22.734	100	28.072	100	62.452	100
Industrial land	1.630	8.5	1.974	10.2	1.989	21.9	8.513	30.3	16.188	25.9
Storage land	0.242	1.2	0.060	0.3	0.488	2.2	1.255	4.5	0.214	3.4
Out of the city traffic land	0.098	0.5	0.102	0.5	0.211	0.9	0.811	2.9	1.958	3.1
Residential &public land	15.366	79.9	15.347	79.1	15.321	67.4	14.555	51.8	33.644	53.4
Road land	0.558	2.9	0.568	2.9	0.616	2.7	1.245	4.4	4.497	7.2
Gardening land	0.415	2.2	0.421	2.2	0.369	1.6	0.673	2.4	1.234	2.0
Other land	0.920	4.8	0.938	4.8	0.74	3.3	1.020	3.6	2.791	4.5

Source: reference [43]

The growth of residential land use resulting from the increase in population has been the leading factor of urban land expansion since the 80s. In Suzhou-Wuxi-Changzhou region, from 1982 to 1992, the residential and public land increased by 1908.9 km^2, 1.3 times, during the decade, making up 52.8% of the total expansion of urban area.

New urban districts and economic and technological development areas are the new forces during the growth of urban land. In Suzhou, since 1982, a new urban district of 20 hm^2 has been built to the west of the old one and continues to take shape. In 1990, a high-technology development area was built to the west of the new one, with an area of 16.8 hm^2. At the same time, a Singapore industrial area was built to the east of the city with an area of 70 hm^2. The total area of the urban and planning districts amount to 100 hm^2. The new districts and development area have been the most powerful forces in the growth of Suzhou City.

Before the 80s, the development of small towns was mainly by the expansion of industrial land occupying limited croplands. In the second half of the 80s, the town scale expanded further with the opening–up, fast development and the construction of a new area. In Taicang, urban area expanded swiftly and violently from 1978 to 1984, resulting from the development of township and village enterprises. Town land increased 81.7% in 1984 from that in 1974, 0.7 times in 5 years as much as that in the previous 25 years, and the industrial land increased by 66.2 hm^2, 41.7% of the total expansion.

The flourishing of economy resulted in transportation networks for the Suzhou-Wuxi-Changzhou region to develop very fast. Besides the building of the Shanghai-Nanjing highway at present, the road communication networks connecting cities and villages are serried, and the density of road is enlarged. Consequently, roads now occupy usable land. The development of land used for communication is an embodied mark of the growth of the economy in this region.

In recent years, arable land has declined because of the growth of urbanization, economic systemization, and the expansion of town and traffic land. In 1985 the arable land of Suzhou decreased 36.8×10^4 hm^2. In 1992, it decreased by 4.9%, to 35×10^4 hm^2 in 7 years. In Wuxi, it decreased by 7433 hm^2, 3.9%. While in Changzhou, the decreased arable area was 2390 hm^2, 1.2% of that in 1985. The changes of arable land are listed in Table 10.

The expansion factors for growth of town resemble those for urban land. The growth of industrial land was the leading factor before the 1980s, on average, making up over 40% of the whole land used for town expansion. Industrial land declined to the second position in recent years, making up 17.7% of the total land occupied by towns, while the residential land became the leading factor, making up 52.8% of all. Moreover, the functional land-use, such as traffic, greenery, and so on, played an important role, among which the rate of road land amounted to 13.85%.

Table 13 The changes in arable land in Suzhou-Wuxi-Changzhou

	Region	Arable land (10^3 hm^2) 1985	Arable land (10^3 hm^2) 1992	Change (%)		Region	Arable land (10^3 hm^2) 1985	Arable land (10^3 hm^2) 1992	Change (%)
Suzhou	The inner areas	4.67	7	49.9	Wuxi	The inner areas	4.00	3.72	-7.0
Suzhou	Chang-zhou	70.00	68	-2.9	Wuxi	Jiangyin	52.00	51.01	-1.9
Suzhou	Zhang-jiagang	49.33	48	-2.7	Wuxi	Xi-shan	58.67	55.83	-4.8
Suzhou					Wuxi	Yixin	76.67	73.33	-4.4
Suzhou	Tai-chang	44.67	42	-6.0	Changzhou	The inner areas	2.67	7.25	171.5
Suzhou	Kun-shan	58.00	56	-3.4	Changzhou	Wu-jin	95.33	89.35	-6.3
Suzhou	Wu-xian	79.33	74	-6.7	Changzhou	Jin-tan	43.33	43.07	-0.6
Suzhou	Wu-jing	62.00	55	-11.3	Changzhou	Shu-yang	64.67	63.94	-1.1

Source: reference [43]

The development of township and village enterprises promotes the urbanization of life styles. It is shown in two ways. One is that it offers peasants the chance of engaging in non-agricultural production, increases peasants' income and changes their living conditions and life styles. The other is that it adds investment to the construction of villages and towns, which changes rural appearance, and improves the rural environment and so improves rural people's quality of life.

The increase in the peasants' income narrows the gap between urban and rural income. In 1978 for Wuxi City the income of the peasants was 32.9% of that of urban workers on average, and rose to 54.3% in 1990. The changes in the peasant's life style in South Jiangsu are reflected in three aspects. The first one is the obvious improvement in living conditions. The ratio of the storied building has been raised over 98%, with 32 m^2 living area per capita. The second one is that the life style of the peasant is transforming from a rural style into an urban style. Lastly there is the emergence of a large number of entrepreneurs from the peasants.

The rapid development of the economy in rural area results in the improvement of the farmers' environment. In Wuxi County, networks of village roads throughout the county were set up, which were all concreted. The rate of population with access to tap water is over 70% and the telephones per hundred persons is 3.8. Culture centers and theatres have been established in every town. Moreover peasant's parks were built in some towns.

In 1986, in Jangyin city for urban residents, the income per capita was more than 900 RMB yuan, and for rural residents, more than 800 RMB yuan. The difference was very little. Ten years later, in 1996, the income for an urban resident on average sharply increased to over 6800 RMB yuan, 6 times more than that in 1986. The income per capita in rural area also increased by 4.6 times, to above 4800 MRB yuan. The speed of growth was second to none. At the same time, the Engle coefficient of the residents in the city totally dropped from 47.3% in 1986 to 40.01% in 1996, but in rural area it went up-and-down largely and didn't take on an obvious declining trend. It indicated that the improvement of quality of life in the countryside lagged, relatively, behind that for urban districts.

In 1986, the average expected longevity in Jiangyin City was 69.72 years, the male was 68.31 years and the female was 71.14 years, which approached the advanced level in the world.

In 1997, the GDP of Jiangsu province was 668.03 billion RMB yuan, 8.7 times more than that in 1978. The annual average increase was 12.7%. The income for peasants per capita for the whole province was 3270 RMB yuan, 19.1 times more than in 1978, and the annual average increase was 17.4%, exceeding the GDP increase for quantity and speed. The cash and deposit for peasant per capita got 2410.3 RMB yuan and the family's income on average was 9378.4 RMB yuan. The income for urban residents per capita reached 5192 RMB yuan, increasing 17 times of that in 1978, and the annual average increase was 16.4%, which also surpassed the GDP increase in quantity and speed. In fact, it increased by 7% each year, even after deducting the effect of the rise in commodity price in succession.

8. Effect: Environmental and Ecological Impacts on Regional Development

It is sure that human activities affect environment and ecosystem. Rapid development of regional urbanization and rural industrialization has a great impacts on the ecological environment and will affect regional sustainable development. The effects can be analyzed from two aspects, that is, soil and human health.

The relationship between people and land will face a new challenge and the problem will become more serious than ever. There were 6766.90×10^4 persons in Jiangsu Province in 1990, 3254.90×10^4 persons more than that in 1949. Even under condition of family planning, the population increased 1.2% yearly. In 2000, the total population will be 7604.21×10^4 persons, and in 2010, 8590.14×10^4 persons. With the increase of population and the decrease of arable land, the density of population increased little by little, from 342 persons/km^2 in 1949 to 659 persons/km^2 in 1990. However, the area and the arable land that each person had decreased accordingly, from 0.29 hm^2 and 0.157 hm^2 in 1949 to 0.15 hm^2 and 0.067 hm^2 in 1990 respectively.

The problem focuses on the unceasing decrease of arable land and the progressive increase of demand for consumer goods, mainly food. After liberation, the total grain yield in Jiangsu increases 4.36 times, from 748.5×10^4 t in 1949 to 3263.25×10^4 t in 1990, but the grain yield per capita only increased 1.26 times because the population increased so rapidly that most of the increase in grain yield was consumed by the increasing population. The capability of land sustaining human basically was the amount of arable land per capita. The grain yield per capita, which waved at 500 kg from 1984 to 1989, decreased to 482 kg in 1990. The grain yield per mu has been fluctuating since 1984 when it reached 484 kg. It is foreseen that the arable land will decrease to 446.72×10^4 hm^2, and the grain yield per capita will decrease to 464.7 kg although the total grain yield will be 3534×10^4 t in 2000 from improvement to middle and low-yield arable land with the grain yield per mu raised by 50 kg.

Table 14 Forecast of population, arable land and grain yield in Jiangsu

	Population (10^4 persons)	Arable land (10^4 hm^2)	Grain yield per mu (kg)	Total grain yield (10^4 t)	Arable land per capita (hm^2)	Grain yield per capita (kg)
1990	6766.90	455.79	477.40	3264.15	0.067	482
2000	7604.21	446.72	527.40	3534.00	0.059	464.7

The situation for human health can be illustrated using Jiangyin as an example. From 1952 to 1996, the recorded number of patients getting infectious diseases was 308925 persons, 6865 persons annually. 67378 of these patients were infected by enteric infectious disease, 75 of whom died. The rate of enteric infectious disease to infectious diseases reached the first high tide in the period from 1952 to 1956, from 23.67% to 52.66%. In the period from 1957 to 1963, the rate was lower than 15.24%, the lowest 0.14% from 1961 to 1962. Then it got its second high tide, between 9.13% and 31.54%, from 1964 to 1971. From 1972 to 1977, it decreased again to 0.54-4.93%. The rate rose rapidly after 1978, from 32.54 to 45.20%, in the period from 1978 to 1979, up to 98.17% in 1988. The Quarantine Station of Jiangyin has made a great effort in the prevention and treatment of infectious diseases and made splendid achievements. Apart from enteric infectious diseases, other infectious diseases were all controlled well. It is because of the neglect of environmental protection and sanitation with economic development in past 20 years that the morbidity of enteric infectious diseases rose.

Urbanization and industrialization of Jiangyin brought about many problems because a great number of land resources were occupied. The original landscape was transformed from producing mainly biological goods into combined development of biological production, industry and the construction of city and town so that the ecological services of the soil were interfered with, which was the direct cause of many problems.

The decrease in the capability for land to sustain people was an important cause of ecological problems. In 1997, there were 49.67×10^4 mu of plough land in Jiangyin. In 1978, yield per mu was 268 kg. However, 21.75×10^4 t yields of grain in 1978 could sustain 98.46×10^4 persons, of 220.9 kg per capita, but in 1997, the yield of grain per capita was only 202.17 kg. The decrease in the capability of land to sustain people was an important cause of ecological problems.

With the decrease in arable area, it is a necessary and effective way to raise cropping index in order to get and keep original level of production. In 1997, the cropping index in Jiangyin was between 180% and 200%. It is indispensable to have a series of relevant measures in order to use soil sustainably because the soil is used excessively. Biological diversity of the ecosystem decreases because a great amount of land is used by industry or non-agricultural industry. Many components are excluded from the ecosystems to obtain a high yield for some special crops. The number of biological species in the ecosystem is less and less so that the stability of the ecosystem is decreased.

The major cause bringing about the stressing effect on the physical environment is a lack of effective and efficient chain and web of production and process due to rapid industrialization. Materials and energy cannot be recycled or transformed efficiently so that many products or by-products are accumulated on a large scale.

It can be concluded on the basis of analyzing ecological essence of urbanization and industrialization of rural area from the structural analysis of agricultural ecosystem that now people excessively depend on techniques that are not mature well and that the usage of microorganism is neglected. The proportion between the primary production and the secondary consumption is not proper. For example, the total production of straw all the country each year is 6×10^8 t, but 40-50% of the straw is used as fuel and only 25% as forage. Most of the primary and secondary productions can not be transformed by appropriate process to increase their value because of lack of process links, low profit and excessively high proportion of one species of animal or plant.

In the structural web, a stress effect on environment resulting from the development of the system mainly is attributed to the irrationality of the structural web. The irrationality of the structural web has three respects. The first one is that because of border limitation, the components of the system are scattered so excessively in space and time that it is difficult to found the relation of web. The second one is that the relationship of web is still not formed completely so that there is no necessary links among industrial chains. The third one is that the functions of social components in the system are neglected. Therefore, the structural relationships among components are merely tree-shaped or linear, not circular or web-shaped. The strategy of development focusing on isolated components or part structure, whose side effects are thought very little, in order to achieve developmental goals of part section will give rise to unreasonable results

In Jiangyin, some problems exist, which will influence urbanization there. The level of urbanization is not very high, and the infrastructure is still not perfect. Compared with the surrounding cities, its special individuality is not obvious. It wants excellent scientific and technical staffs, especially in the fields such as management, foreign economy, foreign trade, foreign language, computer and environmental protection. At present, the proportion of staffs in different fields is unreasonable. The problems of fund are serious and must be solved properly to achieve developmental goals. The competition next century in South Jiangsu, domestic and international markets is more and more intense. Traditional industry and production, whose structures are not very reasonable, becomes less and less fashionable. Meanwhile, newly-rising industry and production is not developed adequately.

Highway network is not perfect. Land and water traffic is not matched well each other, and especially, the deep water bank line of the Yangtse River is not used sufficiently. The management system of harbors is complicated and inefficient. The equipment in the harbors is aged. The construction of harbors has lagged behind for a long time. The primary energy source, mineral resources and raw materials are seriously inadequate so that the capability of production in some industries is wasted and financial resource inadequate. The heavy tasks of technological reformation and construction of city is not harmonious extremely. Environmental pollution becomes obvious. Meanwhile, the arable land becomes less. If the trend continues with no control, it is inevitable that the normal development of society and economy will be constrained confined. These problems severely influence economic development and opening to the outside world of Jiangyin, even to the Suzhou-Wuxi-Changzhou area.

For estimating correctly the sustainability of Jiangyin, the measure of eco-footprint was used. This measure translates all the consumed natural physical goods into worldwide average biological productive areas per capita in different basic forms of land, i.e. *ecological footprints*. In the recent 30 years, rapid expansion of urban construction has caused obvious reduction in land assets and this trend is shown in Table 15.

Table 15. Ecological asset appropriation by urban expansion in the recent 30 years

Period	1970-1980	1980-1990	1990-1998
Change in land asset (ha)	632.89	338.92	2248.06
Annual average appropriated land rate(ha y^{-1})	63.3	33.9	224.8

The appropriation rate became much greater decade by decade. In the recent 10 year, the appropriation of land asset rose at an average rate of 224.8 ha y^{-1}, much higher than that in the past two decades. With the development of city economy, the GDP per capita has become greater and greater, rising from 624 RMB yuan in 1980 to 24,000RMB yuan in 1998, but the arable land per capita decreased from 0.05 ha in 1980 to

0.04 ha in 1998 and the capacity of land asset for sustaining current living quality has greatly been stressed.

From the brief analysis above, It can be found that the expansion of Jiangyin city has made clear the large-scale shifts of ecological assets into human economic assets, and these shifts are reducing available maximum capacity of ecological assets to support the city operation.

According to available statistical data in Jiangyin, the total annual consumption of ecological assets in 1998 was estimated. From the calculation, it is found that the main consumption of ecological assets are driven by the city's production and the requirement of living levels, of which the current level of living quality occupies a large amount of raw ecological assets. Most of these ecological assets that have been consumed are not substitutable by means of human present technology, and so become the essential supports to the city, as is the reason why the city has to be dependent on its nature. In addition, Jiangyin depends on not only its own ecological assets, but also on ecological assets produced beyond its administrative boundary.

The results are showed in Table 16 in terms of ecological footprints, which is denoted by land asset ecological footprint components. The main component of land asset ecological footprint is fossil energy land, which indicates that the appropriated ecological assets in Jaingyin mainly come from outside the city, in the meantime, the component of land asset footprint for the built-up area places second, the forest places third, and arable land fourth. This result indicates a typical trend in the urbanization in South Jiangsu province, that is, the urbanization is a process of increasing appropriation of fossil energy, forestland and arable land.

Table 16 Components of land assets footprint in Jiangyin, 1998

Basic categories of land assets[1]	Land asset footprint components (per capita ha)	Equivalent factor[3]	Total equivalent land
Fossil energy land[2]	0.909843	1.1	1.000827
Arable land	0.000221	2.8	0.000618
Pasture	0.000150	0.5	0.000075
Forest	0.016416	1.1	0.018057
Built-up	0.012239	2.8	0.034268
Sea	0.000020	0.2	0.000004
Total	0.938887	-	1.053849

Note: 1. Among different forms of basic land, their denominator is transformed into a land unit area with worldwide average biological productivity. 2. fossil energy land is calculated according to the equivalent amount of carbon between forest land and different types of fossil fuels. 3. Equivalent factor indicates the productivity difference among different landforms.

According to the statistical data in Jingyin city, the biological capacity of the city per capita was estimated, transformed to global biological capacity per capita. The results are shown in Table 17.

Table 17 Land ecological assets capacity in Jiangyin and the world, 1998

Land category	City area (per capita)	Yield factor[1]	Per capita yield adjusted world average land (ha)	Global yield equivalent area (1998)
CO_2 absorption land	0.001756	2.6	0.005023	0.00
Arable land	0.045675	3.1	0.3964623	0.68
Pasture	0.000000658	2.4	0.00000079	0.30
Forest	0.002866	2.6	0.0081973	0.97
Built-up	0.020553	3.1	0.1783978	0.16
Sea	0	1.0	0.000000	0.11
Total existing	0.070851	-	0.588080	2.22
Total available(minus 12% biodiversity protection land	-	-	0.5175	1.95

Note: 1. Yield factor indicates the ratio of city's productivity of land assets and global average land productivity.

According to Table 15, the maximum land biological capacity is 0.5881 ha, and available land biological capacity is only 0.5175 ha, which is only 49% of Jiangyin's land ecological footprint, so we got 0.54 ha of an ecological deficit with current urban developmental and living level. In Comparison with the global land biological capacity, the difference between them has arrived 1.44 ha .

Jiangyin is a highly developed city in South Jiangsu, with the continuous economic and population growth. The appropriation of land assets has become a more and more serious problem. In the recent 10 years, this figure has arrived at a value of 224.8 ha y^{-1}. Due to its very limited available land biological capacity, Jiangyin is currently facing a conspicuous contradiction between its own supply of land ecological assets and its real demand to sustain its current levels of production and living quality.

From a viewpoint of ecological footprint, in Jiangyin, the real demand of ecological assets for the city development is 1.05 ha in 1998, in contrast, the available supply of ecological assets is only 0.52 ha. The ecological deficit of land assets has reached a value of 0.54 ha, scaled globally to be a value of 1.44 ha. To keep the city's current level of development sustainable, Jiangyin has to make itself more dependent upon the imports of goods and services of land assets from outside the city, or largely reduce its size of population and the level of production and living quality to fit into its own supply of land assets.

9. Response: Response of Local Government and Society to Environmental Issues

To response to the urgent environmental challenge, many measures have been taken by the local government. These are: Ecopolis development and institutional reform including eco-agriculture and eco-village development, behavioural inducement and capacity building, cleaner technology innovation and transferring. A number of chain link contracts of responsibility for the physical and social environment have been made in the area between mayors and different departments of government in different level governments from province to villages, between governments and EPA, and between EPA and sectional leaders and company managers. The contents of the contracts include environmental targets, responsible persons and institutes, cooperation persons and institutes, evaluation indicators, incentive methods. Besides this, an eco-civilized city campaign has been carrying out in the cities.

In order to guide the small towns to develop towards their sustainability in time, the provincial CPC and government work out two social and strategic projects, Basic Farmland Protection Zone and Rural Construction Plan. The provincial Science and Technology Commission has provided the provincial decision-makers with scientific support and basis, and launched in 1996 a project "Pilot study on the harmonious development between environment and economy at small towns". Some towns were studied and a system of estimating sustainability of town was established with a view of strategic perspective of sustainable development of small towns, and aiming at environmental, social, economical, sustainable, rapid, harmonious and healthy development. The contents of this system include economy, sociality and environment.

According to the document from the State Environmental Protection Agency, 5 towns of Jiangsu were chosen as ecological pilot zones. The common characteristic of these models is to protect the quantity and quality of eco-environmental resources for sustainable development, reduce energy, water and material consumption, decrease the production of wastes, realize clean production and healthy material re-cycling, strengthen "up-to-standard waste release", "total discharge control", "environmental planning", and "environmental comprehensive management", and realize a synchronizing, harmonious and healthy development of environmental, social and economic benefits.

A lot of work has been done in urban environmental management in Jiangyin City in recent years. The work involved the establishment of regulations and organizations, in the implementing of the laws, in the enforcement of actively supervising the development of comprehensive treatment, in the construction of hygienic villages and towns and in the practice of education widely, and so on.

10. Strategies: Ecological Development Strategies

China is a developing country. Developing the economy and protecting the environment and the ecosystem are two tasks with the same importance. In order to achieve these tasks, some proposals should be put forward.

According to the nature of regional natural-social-economic complex ecosystems, social humanistic landscape as well as natural landscape, we ought to make a rational planning. The dominating feedback of current rapid urbanization in Yangtze Delta is positive one characterized by huge modernization demand and market orientation. To turn the positive feedback into negative one and turn loss into gain, one has to comprehensively understand its dynamics and cybernetics, to make ecologically compatible planning, design and construction through technological innovation, institutional reform and behavioral inducement. This is just the task of urban ecology, which can be divided into three categories: systems ecology, applied ecology and engineering ecology.

In term of the real conditions of the industry, different measures should be carried out. In developed areas, development should focus on the strength of township industry and sideline. It is necessary to give an impetus on agricultural scale-production and rural urbanization so as to make rational use of land resource. In developing industrial areas, township industrialization should be concentrated on the township level and quickening the rural town construction. Principally, new programs are not admitted at village level.

It is rudimentary demand to adjust town industrial structure, ameliorate enterprise internal environment, enhances scientific concentration in their product. With the rearrangement of regional industries, the town industries stressed on the labor-density industry instead of technical-intensive industry with higher management level. Furthermore, they should attract urban surplus brains into their enterprise. They should be encouraged in developing agriculture-oriented enterprises. As a supplement industry, the current rural enterprises should manage to make a stable and affiliated connection with urban enterprises, and the government should facilitate local enterprises to actively cooperate with big state-owned enterprise and foreign trade companies. The enterprise with higher energy and material consumption, severe pollution and bad product quality should be uncompromisingly shut, stopped, changed or merged into other enterprises. In the future, we should strengthen macro- and micro-regulation and adjustment, and slow down the over-high developmental speed to appropriate one.

In order to propel the enterprise forward to a large extent, we must take the following measures: to enhance the governmental and social service function and macro-regulation; to decrease the governmental interference in enterprise to realize the social institutional reform; to find new sources and save material flows; to carry out talent scout; to increase scientific and technological capability; and to undertake the distribution policies according to work and other factors with a view of changing the productive pattern and increasing market competitive ability.

The central and local governments ought to set about enacting the management law of township industrial environment. The government ought to control the diversion of pollution industry into rural areas, and lessen the pollution area. New ventures should be concentrated relatively.

An appropriate relationship between the agriculture and industry in the countryside should be established. The township industries have to regard agriculture as their main objective. Some active measures should be taken for agricultural production and guarantee a certain proportion of labor force within agro-ecosystems. The government should develop the primary industry, and by no means give up the basic agriculture.

In order to promote population floating reasonably and orderly, census register system should be reformed and perfected and new regulation of census register management should be set up. One's residence register should shift with his/her professional changes. In the meantime, some management methods should be practiced, and the standard management of temporary residents should be enforced.

Management regulation of floating labor should be established on the base of macro-integral benefits, and their register should be unified. Complete management of immigrants' lives and social service should be reinforced in order to attract them to keep their minds on working and to make their efforts for the stable and safe production of enterprises. A proper attraction policy for talent should be set up to draw brain from outside.

Overall strategies planning will take on urban system development in South Jiangsu. Suitable management institutions and organizations of city and town group need to be established for the newly emergence of medium and small towns developed or developing. The set of urban system will be based on multi-directions. Different towns will have their own goals, diversity and mutual compensation.

Industry development will found the quality of product and service as the starting point of occupying and developing market. The process of production, and consumption should minimize the negative influence, and set up reliable supervision system on both environmental and ecological management. Industrial structure will be adjusted further. Typical model of ecological industry will be established according to the development of green industry.

Ecological planning and overall adjustment of present pattern of land use will be carried out throughout the region. It's necessary to control, plan and supervise the use and development of land from the ecological, social and economical positions.

The program of overall social service system and perfect organizations of service and regulation will be set up in order to meet the dwellers' demand on living diversity. Urban environmental construction and its quality will be improved and protected. On the initiative of healthy ecological life style, health protection system of communities can be reinforced in order to promote people's health development both physically and spiritually. A new type of culture in harmony with nature will be advocated and created step by step in the aspects of consciousness, ideas and behaviors.

Environmental accounting should be underway after investigating and supervising environmental resources' condition thoroughly. Then a plan is made on environmental development to set protection goals of districts or towns and to establish detail practical regulations. Regulations about products' cost accounting of environmental pollution should be established. Regulations of pollution discharge permit license should be implemented.

Ecological industry is different from the traditional one, in which energy, information and materials flow can be recycled regenerated and metabolized. The bio-mass will be recycled. Ecological engineering of decentralized treatments will be constructed and the wastewater will be treated in order to be reused. The other ecological engineering such as compound fertilizers industry, green chemical industry, green foodstuff industry, ecological traffic industry, ecological building industry, ecological restoration industry, and so on will develop further.

The key contents of ecological culture include value, behavior and life style, system construction and ecological culture education. With the development of wide public participation and ecological education, the education is focused on polarizing ecological environmental ideas, promoting the formation of ideas of ecology value, advocating ecological life style and praising highly about good personal ecological behavior. In the aspects of management system and construction, we will integrate local governmental behaviors into public ones, and vice versa. The opening-up mechanism among government, specialists and the public will be the core of management transformation system. Relevant ecological laws and policies will be set up. The focus of ecological education will be put on the change of the national ideas and the formation of eco-value.

11. Conclusions

Dramatic economic and environmental changes have taken place in China due to rapid and uneven urbanization and industrialization. Yangtze Delta is a very successful example in the development during this process. In the region, especially along the Suzhou-Wuxi-Changzhou corridor, flexible policy for development, viable decentralized institution, long tradition of industrialization, strong technical support from large cities such as Shanghai, and rich human and natural resources have stimulated the extraordinary growth of local economy. It has become one of the most rapidly regional urbanizing and rural industrializing areas in China. Now it is one of the most developed regions in China. People's living quality has been improved greatly. The economic achievement, which can largely be attributed to the development of town and village enterprise, is very great. With the urbanization and industrialization, the concentration of people becomes obvious. Several millions labors immigrate into this region from outside.

Unfortunately, along with the positive economic growth, the negative environmental impacts are also significant. There are two problems that are the most serious. The first one is water pollution and the other is the deterioration of ecosystem, especial the arable land area decreasing. Because of water pollution, people's daily life and industrial and agricultural production are influenced badly. With the city area expanding unceasingly, the arable land area in Yangtze Delta shrinks step by step, which results in land waste, soil fertility reduction and soil degradation. This is a stern problem. The South Jiangsu has become a region importing grain due to arable land area decreasing. For controlling environmental pollution and resisting ecological deterioration, the local government has done many works including establishing local laws and regulations, founding environmental teams, constructing ecological pilot zone and so on.

Since 1978, China has been transforming from an agricultural society into an industrial society, from planned economy to market economy, from a homogeneous and unitary society into a heterogeneous and diversified society. The pace, depth, and magnitude of this transition, while bringing about benefits to local people, have exerted severe human ecological stresses on both local physical and cultural conditions and regional ecological landscape. Man's life support system faces serious threat. This threat mainly comes from human's actions. Sustainability can only be assured with a human-ecological understanding of the complex interaction among environmental, economic and social/cultural factors and with comprehensive planning and management grounded in ecological principles. Experiences and lessons in China suggest a revolution in value change, scientific methodology and technological instrument is absolutely necessary to encourage a real sustainable development grounded in sound human ecological principles.

References

1. Research Group of Small Town in Jiangsu Province• Regional Analysis in Small Town—Collection of Materials of the Small Town in Jiangsu Province• China Statistical Publishing House
2. Statistical Bureau of Jiangsu.1998 Statistical Yearbook of Jiangsu• China Statistical Publishing House, 1998
3. Statistical Bureau of Wuxi. 1998 Statistical Yearbook of Wuxi• China Statistical Publishing House, 1998
4. Statistical Bureau of Suzhou. 1998 Statistical Yearbook of Suzhou• China Statistical Publishing House, 1998
5. Statistical Bureau of Changzhou. 1998 Statistical Yearbook of Changzhou. China Statistical Publishing House, 1998
6. Statistical Bureau of Jiangyin• Yearbook of Jiangyin• China Statistical Publishing House, 1998
7. Civil Administration Ministry and Construction Ministry of People's Republic of China• Encyclopaedia of Chinese Counties Vol. East China's Chinese Social Academy Publishing House, 1998
8. Tong Chuan, 1997. Study progress on indicators for sustainable development. Shanghai Environ. Sci. Vol. 16 No. 9.
9. Zhang Kunmin, 1997. Sustainable development and its practice in China. Shanghai Environ. Sci. Vol. 16 No.9
10. Qu Geping, 1997. Study on strategies of sustainable development and urban development. Shanghai Environ. Sci. Vol. 16 No. 1
11. Hu Yanzhao, 1996. Study on economic, social and environmental sustainable development. Shanghai Environ. Sci. Vol. 15 No. 4
12. Wu Lindi, 1995. Preliminary study on indicators of environmental, social and economic harmonious development. Shanghai Environ. Sci. Vol. 14 No. 9
13. Guo Huaicheng, 1995. Study on urban water environment and social, economic sustainable development. Journal of Environmental Sciences. Vol. 15 No.3
14. Shi Zhuomin, 1996. Study progress on urbanization and its influence on urban eco-environment. Journal of Ecology Vol. 15 No. 1
15. Chen Guojie, 1995. The provincial differentiate and its changeable trend of economic development in Yangtze River Valley. Resources and Environment of Yangtze River Valley. Vol. 4 No. 1
16. She Zhixiang, 1995. Productive forces layout, infrastructure and urban development in Yangtze Delta. Resources and Environment of Yangtze River Valley. Vol. 4 No. 2
17. Wang Hesheng, Yu Xiaogan, 1998. Study on issues of Yangtze economic development. Geography and Land Study. Vol. 14 No. 2
18. Ma Daming, 1998. Sustainable development on township enterprises and environmental protection. Geography and Land Study. Vol.14 No.2
19. Wang Hesheng, Yu Xiaogan, 1997. Study on the principle and model of development along Yangtze River. Geography and Land Study. Vol. 13 No. 4
20. Duan Mubin, Zhang Bujian, 1997. Study on development of small town in Zhejiang Province. Geography and Land Study. Vol. 13 No.3
21. Yu Shenguan, 1996. The strategic consideration on population, resources, environment and sustainable development in Kunshan city, Jiangsu Province. China population, Resources and Environment. Vol.6 No. 1
22. Chen Jiaqi, 1994. Regional development of Yangtze Delta and population, resources and environment. China population, Resources and Environment. Vol.4 No. 4
23. Shou Guoqing, 1997. The mechanism study on population gathering and distribution of Jiangyin City. Economic Geography. Vol. 17 No.1
24. Zhang Xiaolin, 1996. Study on development of rural urbanization in South Jiangsu Province. Economic Geography. Vol. 16 No.3

25. Wu Binghuai, 1998. The overall development for regional cities and the adjustment for the land use structure in old cities-A case study in Changzhou. Urban Planning. Vol. 22 No. 1
26. Lin Shitao, 1990. Some new knowledge on small town plan. Urban Planning. Vol.1
27. Yang Dongtao, Xiong Lixin, 1997. Investigation and analysis on township enterprises development in Jiangsu Province. Agricultural Economic Issue Vol. 12
28. Wang Yi, 1991. The measure though for urban and rural economic harmonious development in developed region of coastal areas. Agricultural Economic Issue Vol. 1 No.3
29. Li Wuwei, 1991. The structure adjustment and modernization of China township enterprises. Agricultural Economic Issue Vol. 1 No.3
30. Study on urban and rural economic harmonious development in opening zones of coastal areas of Jiangsu Province. Agricultural Economic Issue. No. 11
31. Chen Wen, Yu Xiaogan, 1997. Consideration on feature, problem and development of Yangtze industrial construction. Geographic Sciences. Vol. 17 No. 2
32. Wang Heping, Dai Zhixi, 1997. Study on arable land use and its countermeasure of Jiangsu Province. Journal of Nanjin Agricultural University. Vol. 20 No. 1
33. Ma Suluan, 1990. Analysis on immigration and floating feature of population in small town—A case study in the cities of Jiangsu Province. Population Study Vol.4
34. Wang De, 1989. The population transformation during rural urbanization and urbanization's indicator and level in South Jiangsu. Bull. Of Nanjing Inst. of Geography and Limnology, Acad. Sinica. Beijing Scientific press.
35. Hong Changshi, 1989. The contents and methods of comprehensive developmental plan at port and along Yangtze River region of Jiangyin City. Bull. Of Nanjing Inst. Of Geography and Limnology, Acad. Sinica. Beijing Scientific Press.
36. Li Min, 1994. Study on population caring capacity of land resources of Jiangsu Province. Land and Natural Resource Study. No.2
37. Su Biyao, 1994. Study on use potential of land resource in Yangzhou City of Jiangsu Province. Journal of Nanjing Normal University. Vol. 17 No.3
38. Wu Xinmin, 1995. Study on population caring capacity of land resource in Taixin City of Jiangsu Province. Rural Eco-Environment. Vol. 11 No. 3
39. Ou Minhao, 1995. Countermeasure of reserved land resource development in Nantong city of Jiangsu Province. Resource development and Market Vol.11 No. 4
40. Wang Changgeng, 1995. The steady abnormal development of fishery of Jiangsu Province. Modern Fishery Information Vol. 10 No. 10
41. Qiu Xiaoxin, 1994. Consideration for issues on small town onstruction. Zhongzhou Construction. Vol.4.
42. Yu Xiaogan, 1993. Study on land and regional planning in Yangtze Delta. Beijing Scientific Press.
43. Wang, Rusong and Z. Ouyang, Methodology of the ecological development and scientific catelyzation of comprehensive experimental communities for sustainable development, *China's Population, Resource and Environment, vol.* 7 (3): 11-14, 1997.
44. Wang, Rusong, Zhiyun Ouyang. Ecological integration ---- probing the scientific methodology of human sustainable development, *Chinese Science Bulletin*, vol.41, special issue, 47-67, 1997.
45. Ma, Shijun, Rusong Wang, Social-Economic-Natural Complex Ecosystem. *Acta Ecological Sinica* 4(1): 1-9, 1984.
46. Wang, Rusong and J. Krause, Towards A Sustainable City: Methods of Urban Ecological Planning and Its Application in Tianjin, China, UNESCO, Imprimerie Jouve, Mayenne, 1996.
47. Wang, Rusong and Shijun Gan, Sustainable Technology for Middle and Small Sized Cities' and Towns' Development , China Science and Technology Press, Beijing, 1995.
48. Wang, Rusong, J. Zhao and Z. Ouyang, **Wealth, Health and Faith --- Sustainability Study in China**, China Environmental Science Press, Beijing, 1996.
49. Wang, Rusong, J.Fang, L. Gao and Z. Feng, **Hot Points of Contemporary Ecology**, China Science and Technology Press, Beijing, 1996.
50. Wang, Rusong and Y. Lu, **Urban Ecological Development: Research and Application,** China Environmental Science Press, Beijing, 1994.

51. Wang, Rusong, B.Yang and Y. Lu, **A Decision Support System for Urban Ecological Regulation**, China Science and Technology Press, Beijing, 1993
52. Wang, Rusong and J. Zhou, **Urban Ecological Economics: Methodologies and Demonstrations** , Fudan University Press, Shanghai, 125-237.
53. Wang, Rusong, Dan Hu, From economic prosperity to ecological sustainability --- a theoretical and practical concern of sustainable development in China. *Journal of Environmental Sciences*, Vol.6., No.4: 389-401, 1994.
54. Wang, Rusong. Toward ecopolis: Urban ecology and its development strategy, *Journal of City and Planning,* 18(1): 1-17, 1991a.
55. Wang, Rusong and Ye Qi. Human ecology in China: Its Past, Present and prospect, in: **Human Ecology Coming of age: An International Overview**, S. Suzuki etc. ed., Free University Brussels Press, Brussels, 183-200, 1991b.
56. Wang, Rusong et al. Pan-Objective Ecological Programming and Its Application to Ecological Research, In: (P. Korhonen et al. eds.) **Multiple Criteria Decision Support**, Lecture Notes in Economics & Mathematical Systems, Vol.356, Springer-Verlag, Berlin, 1991c.
57. Wang, Rusong, ed. **Human Systems Ecology**. China Science and Technology Press, Beijing, 1991d.
58. Wang, Rusong and J.Jia et al. Eco-county: Its Scientific Connotation and Evaluation index• Case Study of Human Ecological Planning of Dafeng Eco-county, *Acta Ecological Sinica*, 11(2): 182-188, 1991e.
59. Wang, Rusong, ed. **Human Ecology in China**. China Science and Technology Press. Beijing, 251p, 1990a.
60. Wang, Rusong and Z. Ouyang et al. On Ecological Construction. *Journal of Environmental Science (China)* 12(3): 1-12, 1990b.
61. Wang, Rusong. **High efficiency and Harmonious Relationship: The Principles and Methodology of Urban Ecological Regulation.** Hunan Educational Press, Changsha, 276p, 1988.
62. Yang, Bangjie, R. Wang and Y. Lu **A Decision Support System for Urban Ecological Regulation**, China Science and Technology Press, Beijing, 1992.

Study of Water Resource, Water Environment and Water Ecosystem in Taihu Lake Basin

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1. Background of Taihu Lake Basin

Taihu Lake is one of the five largest lakes in China. This basin administratively includes two provinces and one city, having very dense population, prosperous economy and becoming an important part of China's economy. This study investigates several aspects of water environment in Taihu Lake basin. The case study reviews the situations of socio-economic development, and the status of water resource, water environment, and waste water treatment. In addition, it analyzes the trends in water consumption of socio-economic activities, environmental and ecological changes. Furthmore, this study will assess the Basin's water environmental quality, and explore ecological economic relationships between water resource uses and regeneration. It will provide in-depth examination on the ecological engineering technology system of wastewater treatment, reduction of water consumption, wastewater reuse and recycling, giving some suggestions on sustainable strategies for water resource, water environment and water ecology.

1.1 Natural Condition

Taihu Lake is located in the East of China, between the south of Yangtse Delta and Qiantangjiang River and Hangzhou Bay, 30° 5′ ~32° 8′ N and 119° 8′ ~ 120° 55′ E. Its north borders Yangtse River, south borders Qiantangjiang River, and west borders Tianmushan Mountain, Jieling Mountain and Maoshan Mountain. The East China Sea is to its east. The total area is 36500 km^2, 0.45% of the area of China, 53% of which belongs to Jiangsu Province, 33.4% to Zhejiang Province, 13.5% to Shanghai and 0.1% to Anhui Province. There are seven medium- and large-city, including Shanghai, Suzhou, Wuxi, Changzhou, Hangzhou, Jiaxing and Huzhou, 26 counties or county level cities, including Jintan, Wujin, Liyang, Wuxian, Wujiang, Changshu, Zhangjiagang, Kunshan, Taicang, Jiangyin, Xishan, Yixing, Danyang, Haining, Pinghu, Tongxiang, Haiyan, Jiashan, Deqing, Changxing, Anji, Yuhang, Linan, Nanhui, Fengxian and Qingpu, and 951 towns. The arable land area is 2020.5×10^4 mu. The total population is 3439.88×10^4 persons.

This area is in the monsoon climatic zone, the transition zone between the north of subtropics and the south of subtropics. The climate is governed by monsoon. Four seasons in a year are distinct. The non-frost period is long, 220-246 days. The heat is plentiful, annual average temperature is 14.9-16.2 ℃. The highest temperature is in July, 27.7-28.6 ℃, and the lowest temperature in January, 1.7-3.9 ℃. The accumulated temperature above 10 ℃ is 4760-5200 ℃. The annual precipitation is 1000-1400 mm.

More than half of area in Taihu Lake basin is plain, 27375 km^2 and 66.5% of the total area. The area of hill, including the plains in river valleys, is 16% of the total area, and water area, including rivers and lakes, 17.5%. The altitude in plain area is 2-10 m, in most area, 3-8 m. Hills and mountains are mainly dispersed in the west borders and the southwest region. Maoshan mountain region, the altitude around 300 m, is hill area, located in west. Liyi mountain region is located in the border between Jiangsu and Zhejiang, the altitude 300-500 m. Tianmu mountain region is in Zhejiang Province, the southwest of Taihu Lake basin. Longwangshan, whose altitude is 1587 m, is the highest peak in Tianmu mountain region. In hill region, the soil types change from yellow-brown soil to red-yellow soil due to the influence of climate in the transition zone. In plain area, the soil type is paddy soil.

Table 1 Distribution of different macro-landforms in Taihu Lake Basin

Altitude (m)	Area (km^2)	Share of the plain (%)
<4	9,225	33.7
(in which the area of lakes)	(3,159)	(11.5)
4~5	10,740	39.2
5~6	2,280	8.3
6~7	2,750	10.0
>7	2,380	8.7
Total	27,375	100.0

1.2 Social and Economic Condition

The west and the southwest of Taihu Lake basin are hills and mountainous areas. To the east is the East China Sea. The total area is 36500 km^2, 0.4% of the total area of the whole country, in which the plain is 27400 km^2, 75% of the total area of the basin. The hill and mountainous areas account for 25% of the basin. In terms of administrative relationship, 53% of the basin belongs to Jiangsu Province, 33.4% to Zhejiang Province, 13.5% to Shanghai and 0.1% to Anhui Province. The total population in the basin is 3439.88×10^4 persons, 2.9% of the total population of China in 1994. The population density is 910 persons / km^2, one of the regions with the highest population density in China. Many cities are concentrated in the region. There are seven big or middle cities, which are Shanghai, Hangzhou, Suzhou, Wuxi, Changzhou, Jiaxing and Huzhou, 27 counties (or county level cities) and 951 towns. Now a city and town network has been formed, which centers Shanghai and is consisted of big, middle and small cities. On average, there is a city every 4400 km^2, an organic town every 340 km^2 and a town every 38.38 km^2. The level of urbanization in the basin occupies the first place in the whole country. The industrial output value of the town and village enterprises in the region occupies the first position in China as well. The total tillable area is about 135×10^4 ha., 1.7% of the total tillable area of the whole country. In 1994, the total industrial and agricultural output value was 10389.3×10^8 yuan, 1/7 of the value all the country. The grain yield was 1105.66×10^4 tons, 3% of the total yield of the country. The commercial rate of grain is 26.3%. the total yield of fresh aquatic product was 97.93×10^4 tons, 11% of that all the country, and the total output value of freshwater fishery was 1/4 of that in China. Every year, the revenue from the region takes the first position in China. Shanghai port is one of the biggest seaport in China, whose throughput is 1/3 as large as the total throughput all the country. Taihu Lake basin is one of the regions open to the world. It is sure that the basin will be the locomotive leading the economic development all the region along Yangtze River, even the economic development all the country with the exploitation and development of Pudong District, Shanghai.

Table 2 Background in Taihu Lake Basin, 1994

	units	amount		units	amount
Total area	km^2	36500	Grain yield	10^4 tons	1105.66
Area of plowland	10^4 mus	2020.25	Amount of aquatic product	10^4 tons	97.93
Total population	10^4 persons	3439.88	Cities	Number	7
Total industrial and agricultural output value	10^8 yuan	10389.3	Organic town	Number	27
Gross national product	10^8 yuan	4778.83	Town	number	951

2. Water Resource in Taihu Lake Basin

2.1 Water System in Taihu Lake Basin

Taihu Lake Basin consists of total 219 river courses linking with Taihu Lake. Such a complex river network is influenced by landform, river, tide, water inflows and human beings. Total length of these rivers is 120,000 km and the main watercourse is extended to about 1200 km.

Major rivers of Taihu Basin include the Grant Canal in the south of Yangtze River, Huangpu River, Tiaoxi, Nanxi, Taipu, and Wangyu River. The topography here is flat, the watercourse is short, the water amount is small and those rivers form a fan-shaped drainage system at the lower reaches. There are 189 lakes, each area over 0.5 km^2. The overall area of the lakes in the Taihu Plain is 3159 km^2, accounting for 8.96 percent of the Taihu Basin, which is about ten times high of the national average lake ratio 0.83%, 51.2% of the water area in Taihu Lake Basin. The total area of reservoirs in this region is 73 km^2, 0.2% of the total area of the Basin. In the Taihu Plain lakes there are 9 lakes in which everyone's area is over 10 km^2 and their total area is 2839.3 km^2, accounting for 89.8% of the total lake area. The total area of 180 lakes, each with area under 5 km^2, is only 212.4km^2, accounting for 6.7% of the total lake area (Table 3).

Table 3 Lakes in the plain of Taihu Lake

Region	Lake area (km^2)									
	>10km^2		10-5		5-1		1-0.5		Total	
	No.	area	No.	area	No.	Area	No.	area	No.	Area
YCDM	6	264.34	8	52.10	34	72.62	22	15.20	70	404.26
PHJH			4	29.30	44	78.95	43	20.10	91	128.35
Puxi					1	1.63	3	1.52	4	3.15
Pudong										
Chengxiyu			1	5.29	2	2.79	1	0.65	4	8.73
Huxi	2	235.85	3	21.57	5	13.17	3	2.27	13	272.86
Zhexi							6	3.52	6	3.52
Taihu	1	2338.1							1	2338.1
Total	9	2839.29	16	108.26	86	169.19	38	43.26	189	3158.97

2.2 Water Resource

2.2.1 Distribution of Water Resource

According to the relationship of water supply and demand and the economic situation, this region was divided into seven subregions.

(1) Region in the west of Taihu Lake

(2) Region in the east of Taihu Lake

(3) Region in Chengxiyu

(4) Region in the west of Zhejing province

(5) Plain region in the east of Hangzhou-Jiaxing-Huzhou

(6) Region in Huangpujiang River valley

(7) Centric area of Taihu Lake

2.2.2 Amount of Water Resource

In Taihu Lake Basin, the total amount of water resource a year on average can be counted according the formula as follow:

$$W_t = W_r + W_g - W_{rp}$$

In the formula, W_t is the total amount of water resource (10^8 m^3). W_r is is the runoff volume generated by precipitation (10^8 m^3). W_g is the amount of groundwater supplied (10^8 m^3). W_{rp} is the amount lappedly counted (10^8 m^3).

2.2.2.1 Amount of Precipitation

Precipitation is the main source of the surface water resource in the region. The precipitation is 1000 – 1400 mm. In the Hangzhou-Jiaxing-Huzhou plain, which is in the south of Taihu Lake Basin, the precipitation is higher than that in the north. The precipitation in Huangpujiang River watershed, which is in the east and close to the East China Sea, is higher than that in the west. The south mountainous areas get more precipitation than the north plain areas. The precipitation changes greatly in a year and between years due to the influence of monsoon. The precipitation in the most rainy year is 1 ~ 1.5 times higher than that in the lest rainy year. The relative variability is 15% - 30%. The peak of precipitation is in the period from June to August, about 35% - 40% of the total precipitation a year. The valley of precipitation is in winter from December to February, only 11% - 14%.

2.2.2.2 Amount of Runoff Flow

The precipitation forms surface runoff and groundwater runoff apart from the wastage such as evaporation from water surface or ground, transpiration from plant, adsorption and so on. In different area, the climatic condition, the precipitation and the ground condition are different. Therefore, the runoff volumes in different area are not the same. The runoff coefficient in Taihu Lake Basin is 0.26 – 0.4. The coefficients in the mountainous area and the Hangzhou-Jiaxing-Huzhou plain are higher than that in the north plain area. The average annual runoff in the region is 141.74×10^8 m^3 (Table 4), among which 55.4 is $\times 10^8$ m^3 in Jiangsu Province, 70.7×10^8 m^3, in Zhejiang Province and 15.59×10^8 m^3 in Shanghai. The area of Jiangsu Province is about 8000 km^2 more than that of Zhejiang Province, however the runoff of Jiangsu Province is 15.25×10^8 m^3 less than that of Zhejiang Province. In Zhejiang Province, the average amount of water generated is 58.2×10^4 m^3 / km^2, in Shanghai, 30.5×10^4 m^3 / km^2, but in Jiangsu Province, only 27.4 10^4 m^3 / km^2. Therefore the amount of water generated in unit area in the south plain of Taihu, in Zhejiang Province, is the most abundant.

2.2.2.3 Amount of Groundwater

The groundwater here is the shallow groundwater that can exchanges water with surface runoff. Its replenishment mainly relies on the precipitation. The total amount of the shallow groundwater in Taihu Lake Basin is 55.2×10^8 m^3, whose amount replenished is 23.15×10^8 m^3. In the area on the east of Huangpujiang River watershed, the replenishment is the most, 6.05×10^8 m^3, then, in the west of Taihu Lake Basin, 5.87×10^8 m^3. In these areas, the groundwater resource is plentiful relatively.

2.2.2.4 Local Amount of Water Resource

The local water resource is the sum of the surface water and groundwater except the river runoff or the sum of the local runoff and the replenishment of the subsurface water. In Taihu Lake Basin, the average annual local water resource is 164.99 ×10^8 m^3, 41% of which is in Jiangsu Province, 67.88 ×10^8 m^3, 45.7%, in Zhejiang Province, 75.48 ×10^8 m^3, and 11.3%, in Shanghai, 11.3%.

Table 4 Local Water Resource in Taihu Lake Basin

	Area (km^2)	annual pecipitation (mm)	annual runoff (mm)	local runoff ($10^8 m^3$)	ground-water ($10^8 m^3$)	river runoff ($10^8 m^3$)	local water resource ($10^8 m^3$)
West of the Basin	8880	1079	319	28. 34	10. 04	4. 17	34. 21
East of the Basin	5307	1044	285	15. 10	7. 47	3. 67	18. 90
Surface of Taihu	2338	1069	69	1. 59			1. 59
Plain along Huangpujiang river and the sea	5110	1141	582	15. 59	11. 09	5. 05	21. 63
Cheng-Xi-Yu area	3705	1036	281	10. 42	5. 37	2. 61	13. 18
Shaoxi brook mountainous area	5797	1333	305	40. 20	11. 41	11. 41	40. 20
Hangzhou-Jiaxing-Huzhou plain	6357	1333	582	30. 50	9. 82	5. 04	35. 28
Total				141. 74	55. 20	32. 05	164. 99

Table 5 Inflow in Taihu Lake Basin under different rates of guarantee

	50% rate of guarantee	75% rate of guarantee	95% rate of guarantee
West of the Basin	54.19 × 10^8 m^3	61.21 × 10^8 m^3	70.14 × 10^8 m^3
East of the Basin	60.84 × 10^8 m^3	53.18 × 10^8 m^3	70.36 × 10^8 m^3
Cheng-Xi-Yu area	30.33 × 10^8 m^3	32.00 × 10^8 m^3	43.80 × 10^8 m^3
Plain along Huangpujiang river and the sea	554.8 × 10^8 m^3	554.8 × 10^8 m^3	500.7 × 10^8 m^3
Shaoxi brook mountainous area		0.6 × 10^8 m^3	2.59 × 10^8 m^3
Hangzhou-Jiaxing-Huzhou plain	16.72 × 10^8 m^3	24.62 × 10^8 m^3	24.21 × 10^8 m^3
Total	716.88 × 10^8 m^3	726.41 × 10^8 m^3	711.8 × 10^8 m^3

2.2.2.5 Amount of Water inflow

Inflow means the water from outside. The upper reach of Taihu Lake Basin is a relative close watershed and there is no water inflow originally. However it is between Yangtze River and Qiantangjiang River and close to the East China Sea. The water from rivers and tidewater can be pumped into this region. Therefore the water resource from outside is plentiful. The total water inflow in the Basin is 716.88 $\times 10^8$ m^3 (P=50%) (Table 4). In the part of the Basin belonging to Jiangsu Province, the water resource mainly is from Yangtze River, and the inflow is up to 145.36 $\times 10^8$ m^3 (P=50%), whereas in Shanghai, the inflow is tidewater from Huangpujiang River and the total inflow is 554.8 $\times 10^8$ m^3 (P=50%). There is no other inflow in Shanghai.

2.2.2.6 Total Amount of Water Resource

Water resource is a dynamic resource whose amount changes yearly. It should be the part that can be regenerated every year because it relies on precipitation. Thereby the total amount of water resource in a given region should be the sum of natural river runoff, including local runoff and inflow, and subsurface water supply. In terms of this principle, the total amount of water resource in Taihu Lake Basin under different rate of guarantee can be counted, 876.59 $\times 10^8$ m^3 (P=50%), 854.99 $\times 10^8$ m^3 (P=75%) and 788.74 $\times 10^8$ m^3 (P=95%) respectively. In low flow year, the water resource is 97.85 $\times 10^8$ m^3 (P=50%) less than that in original flow year. In low flow year, the sum of water resource in Jiangsu Province and Zhejiangjiang Province is 295.24 $\times 10^8$ m^3 (P=50%).

Table 6 Amount of water resource in Taihu Lake Basin under different rates of guarantee

	Rate of Guarantee P (%)	River runoff (10^8 m^3)	inflow (10^8 m^3)	total (10^8 m^3)	Replenishment from subsurface water (10^8 m^3)	Total amount of water resource (10^8 m^3)
	50	54.64	145.36	200.01	12.43	212.43
Jiangsu	75	33.97	146.39	180.36	12.43	192.79
	95	7.98	184.3	192.28	12.43	204.56
Shanghai	50	20.41	554.8	575.21	6.04	581.25
	75	19.35	554.8	573.35	6.04	579.39
	95	5.88	500.7	506.58	6.04	512.62
Zhejiang	50	61.31	16.72	78.03	4.78	82.81
	75	39.41	25.22	64.63	4.78	69.41
	95	30.03	26.80	56.63	4.78	61.41
	50	136.18	716.88	853.34	23.25	876.59
Total	75	92.73	726.41	831.74	23.25	854.99
	95	43.89	711.8	755.49	23.25	778.74

2.2.2.7 Amount of Water Resource per Capita in Taihu Lake Basin

In Taihu Lake Basin, average annual local water resource per capita is 861 m^3, which is less than 1/5 of that the whole country, even less than that in Huaihe River watershed where water resource per capita is about as much as 1/4 of that the whole country. Water resource per ha in Taihu Lake Basin is less than 2/5 of that the whole country. Among Zhejiang Province, Jiangsu Province and Shanghai, the water resource per capita in Zhejiang is the most, 1751 m^3 per capita, that in Shanghai, the lest, noly 228 m^3 per capita, and in Jiangsu Province, 469 m^3 per capita. If the total water resource, including local water resource and inflow water resource, are counted together, the water resource per capita is 2666 m^3 (P= 50%). The amount in Shanghai is the most, 5389 m^3, in Jiangsu Province, the lest, 1807 m^3, and in Zhejiang Province, 2334 m^3.

2.2.3 Analysis of Water Supply and Demand

2.2.3.1 Amount of Water Available

The water resource available in Taihu Lake Basin can be estimated. The total amount of water resource in this region is 351.63 $\times 10^8$ m^3 (P=50%) and 367.3$\times 10^8$ m^3 (P=95%) (Table 7). The rate of water usage is 40%-47% around. In Jiangsu Province, the available water resource is 231.89 $\times 10^8$ m^3, which exceeds the total amount of water resource due to largely using the water from Yangtze River and part of water reused. The ratio of reused water is 72.4%. For example, in Zheng-Xi-Yu area, the available water resource is 64.9 $\times 10^8$ m^3, 31.5% of which is reused water, 20.34 $\times 10^8$ m^3. In Shanghai, the water resource is abundant, but a part of the water resource is tidewater so that it is limited to use the water resource. It is expected that the available water resource can be increased up to 344.66 $\times 10^8$ m^3 (P=50%), 354.42 $\times 10^8$ m^3(P=75%) and 367.31 $\times 10^8$ m^3(P=95%) in 2000.

Table 7 Available water resource in Taihu Lake Basin

Region	50% rate of guarantee		95% rate of guarantee	
	Total water resource($10^8 m^3$)	Available water resource ($10^8 m^3$)	Total water resource ($10^8 m^3$)	Available water resource ($10^8 m^3$)
Jiangsu	212.43	231.89	204.71	231.89
Zhejiang	82.81	34.76	61.41	42.42
Shanghai	581.25	80.35	512.62	92.99
total	875.93	351.63	778.74	367.30

2.2.3.2 Amount of Water Demand

The amount of water demand is the water demanded by different departments in the different situation of present production and living and under the condition of rain, flood and draught with different frequencies. The water demanded can be divided into two kinds, one is the water demanded in the rivers that is necessary for shipping and the other is the water demanded outside the rivers. The water demanded outside the rivers includes the water necessary for industry, agriculture involving irrigation, drinkable water by man and livestock and water demanded by village enterprises and domestic water of citizen.

Table 8 The demand of water in Taihu Lake Basin with different guarantee rates

Area	Water demanded by agriculture ($\times10^8$ m^3)	Water demanded by industry ($\times10^8$ m^3)	Water demanded by living of citizen ($\times10^8$ m^3)	Water demanded by man and livestock in rural area ($\times10^8$ m^3)	Total ($\times10^8$ m^3)
		P=50%			
West of the lake	51.37	11.52	0.23	1.12	64.25
East of the lake	48.81	3.86	0.35	0.85	53.86
Zheng-Xi-Yu area	24.66	16.72	0.47	0.77	42.61
Plain along Huangpujiang river and the sea	30.60	44.49	3.84	1.43	80.36
Shaoxi Brook	7.14	0.22	0.04	0.27	7.67
Hang-Jia_hu plain	23.26	2.47	0.49	0.87	27.09
total	185.84	79.28	5.42	5.31	275.84
		P=75%			
West of the lake	54.29	11.52	0.23	1.12	64.25
East of the lake	45.28	3.86	0.35	0.85	50.35
Zheng-Xi-Yu area	26.68	16.72	0.47	0.77	44.63
Plain along Huangpujiang river and the sea	37.40	44.49	3.84	1.43	87.15
Shaoxi Brook	8.86	0.22	0.04	0.27	10.38
Hang-Jia_hu plain	28.00	2.47	0.49	0.87	31.83
total				198.51	288.59
		P=95%			
West of the lake	63.21	11.52	0.23	1.12	76.09
East of the lake	54.20	3.86	0.35	0.85	59.26
Zheng-Xi-Yu area	30.54	16.72	0.47	0.77	48.49
Plain along Huangpujiang river and the sea	43.24	44.49	3.84	1.43	92.99
Shaoxi Brook	9.85	0.22	0.04	0.27	10.38
Hang-Jia_hu plain	29.26	2.47	0.49	0.87	33.09
total					320.3

The amount of water resource demanded by different departments including industry, agriculture and living of citizen under the condition of various rate of guarantee is listed in Table 8. The average annual water demanded is 275.84 $\times10^8$ m^3 (P=50%), 288.59 $\times10^8$ m^3 (P=75%) and 320.3 $\times10^8$ m^3 (P=95%), among which the water demanded by agriculture is 185.4 $\times10^8$ m^3 (P=50%), 67.2%. There are about 2650 $\times10^4$ mu farmland in Taihu Lake Basin, 53% of which, 1399.51$\times10^4$ mu, is in Jiangsu Province. Therefore the water used in agriculture in the area belonging to Jiangsu Province is the most, about 124.8×10^8 m^3, 67.18% of the total amount of water used in agriculture in the region. The total amount of water used by industry is around 80×10^8 m^3, 44.49×10^8 m^3 of which is used in Shanghai, the first position. In Shanghai, 56% of the water is used in industry. The living water consumption in the Basin is relatively small, 5.42×10^8 m^3, and only 2.0% of the total water demanded. The domestic water consumption in Shanghai is the highest, 70.8% of the total consumption of domestic water. Therefore the water demanded in Shanghai, whether by industry or living, is higher than that in other area.

2.2.3.3 Amount of Water Demand Forecast

In terms of the results counted in 1993 by Nanjing Institute of Geography and Limnology, Chinese Academy of Science, the water demanded in 2000 was forecasted. In cities of China, the water used by industry has three sources, which are municipal water supply, deep well self-provided and pumping water from rivers with self-provided equipment. The records of municipal water supply are overall, but the records of water from other sources can not be got. Therefore the water demanded per 10 thousands yuan output value was used as the indicator to enter calculation. On a basis of the industry developing scale in the Basin, it was forecast that the water used in industry would increase to 301×10^8 m^3(P=50%), 3.8 times higher than 79.28×10^8 m^3 in 1980, and in Zheng-Xi-Yu area, from 16.7×10^8 m^3 to 83.63×10^8 m^3. The increase of water used in industry is far rapider than that in agriculture. In the beginning of the 1980s, the water used in agriculture was 185.84×10^8 m^3, occupying the first position of water consumption. According to the predication in 2000, the water used in agriculture will not increase, even decrease slightly somewhere, which will be 165.41×10^8 m^3 (P=50%) or 220.52×10^8 m^3(P=95%). The water consumption by citizen living and man and livestock will go up with the increase of population to 12.53×10^8 m^3 (P=50% and P=95%). In Shanghai, the water demanded increases most rapidly. From 1980 to 2000, the total water demanded will increase 210×10^8 m^3, 6%-7% every year.

The average annual water resource in Taihu Lake Basin is 162×10^8 m^3. In 1971 which was a draughty year the water resource was 80×10^8 m^3 (P=94%) and in 1978, a serious draughty year, only 16×10^8 m^3 (P=98%). Although the water area in the region was abundant and the water resource could be used fully by regulating local runoff, the demand for water was great because 80% of the plowland was paddy field area. In recent years, the national economy and social development were so rapid that the result of forecast was broken through. The districts in large and middle cities, where various industries are concentrated, were constructed uninterruptedly. It was forecasted that from 1980 to 2000, the total water demanded would increase 210×10^8 m^3, 6%-7% every year. Therefore in 2000, the water resource will be deficient badly. The water from Yangtze River, which can meet the demand for water in the region by drawing water, should be taken full advantage of. At present, the equipment drawing water from Yangtze River is not enough so that the capacity of drawing water is small. The condition of drawing water can not meet the demand of economic rapid development for water badly because of the outdated projects of drawing water and seriously filled up river courses. Hence this situation will affect gravely national economy developing sustainably, stably and harmoniously. In the period of "Ninth Five Year Plan of National Economic and Social Development, " the scheme of distributing water resource rationally and effective measure of increasing available water in the Basin should be studied further.

2.2.3.4 Analysis of Water Resource Supply and Demand

It depends on the characteristics of water resource spatio-temporal distribution, hydraulic project of drawing water and condition of driving force that the plentiful water resource meets the demand of national economy. In the calculation and analysis of water resource, we took the measure that the supply was dominated by the demand. Thus the amount of water that can be supplied under different rates of guarantee and the corresponding amount of water that is used are got with the measure.

Table 9 Water resource equilibrium under different rates of guarantee in Taihu Lake Basin
(in 10^8 m^3)

Area	Water resource	Available water resource	Total demand for water	Surplus or deficiency of water	
				surplus	deficiency
		P=50%			
West of lake	90.29	98.17	64.25	37.8	3.89
East of lake	76.38	73.85	53.86	29.18	9.21
Zheng-Xi-Yu area	45.76	64.50	42.61	21.88	
Plain along Huangpujian and the sea	581.25	80.35	80.36		8
Shaoxi brook	31.39	7.67	7.67	0	0
Hangzhou-Jiaxing_huzhou plain area	51.42	27.09	27.09	0	0
Total	876.49	352.44	275.84	140.16	21.39
		P=75%			
West of lake	81.58	90.26	67.19	23.11	0
East of lake	70.39	79.94	50.35	29.59	0
Zheng-Xi-Yu area	40.82	61.63	44.63	17.00	0
Plain along Huangpujian and the sea	579.39	87.15	87.15	49.3	0
Shaoxi brook	20.95	9.39	9.39	0	0
Hangzhou-Jiaxing_huzhou plain area	48.46	31.83	31.83	0	0
Total	841.59	360.2	290.54	119.02	0
		P=95%			
West of lake	80.93	93.82	76.09	20.80	3.06
East of lake	76.26	74.75	59.26	15.91	0.42
Zheng-Xi-Yu area	47.52	63.32	48.49	18.37	3.54
Plain along Huangpujian and the sea	512.62	92.99	92.99		

Shaoxi brook	18.05	9.33	10.38	0	1.05
Hangzhou-Jiaxing_huzhou plain area	43.36	33.09	33.09	0	0
Total	778.74	367.30	320.30		

In terms of the results of balanceable analysis provided by Nanjing Institute of Geography and Limnology, Chinese Academy of Science (1993), the water resource can meet the demand and under different rates of guarantee, there is 70-140×10^8 m^3 surplus water resource. Thereby the water resource can meet the demand for water. However in recent years, the industrial and agricultural production has developed rapidly. More and more people got together there. The water resource is unable to make ends meet. In original year, the deficiency is 20×10^8 m^3, and in seriously droughty year (1978), 120×10^8 m^3.

Table 10 Forecast of water supply and demand in Taihu Lake Basin in 2000

(unit: 10^8 m^3)

area	Water supplied			Water demanded					Deficiency all the year	Period of surplus or deficiency of water (month)
	Runoff of river	Ground water	Total	Total	Farming, forestry and animal husbandry	Industry	Living of citizen	Man and live-stock		
				P=50%						
West of lake	84.60	1.42	86.02	105.78	42.97	60.05	0.96	1.80	-24.74	5~8 1~3
East of lake	75.20	0.81	76.01	94.52	40.62	51.29	1.17	1.44	-21.73	5~7
Zheng-Xi-Yu area	66.35	1.16	67.51	108.15	21.53	83.63	1.79	1.20	-40.68	2~9
Plain along Huangpujian and sea	79.44	0.91	80.35	133.34	30.60	93.30	7.22	2.22	-53.00	1~12
Shaoxi brook	7.53	0.15	7.68	9.41	6.98	1.58	0.11	0.77	-1.76	1~12
Hangzhou-Jiaxing_huzhou plain area	26.63	0.46	27.09	34.91	22.71	8.38	1.28	2.54	-7.82	1~12
Total	339.75	4.91	344.66	486.14	165.41	301.23	12.53	9.97	-149.73	
				P=75%						
West of lake	83.06	1.42	84.48	109.10	46.28	60.05	0.96	1.80	26.64	1~4 8~9
East of lake	79.13	0.81	79.94	97.24	42.84	51.79	1.17	1.44	18.43	6~8
Zheng-Xi-Yu area	60.47	1.16	61.63	110.37	23.75	83.63	1.79	1.20	52.85	1~12
Plain along Huangpujian and the sea	86.24	0.91	87.15	140.14	37.40	93.30	7.22	2.22	53.00	1~12
Shaoxi brook	9.23	0.16	9.39	11.23	8.77	1.58	0.11	0.77	1.83	1~12
Hangzhou-Jiaxing_huzhou plain area	31.28	0.55	31.83	39.83	27.63	8.38	1.28	2.54	8.03	1~12
Total			354.42	507.91					158.78	
				P=95%						
West of lake	92.40	1.42	93.82	121.83	59.01	60.05	0.96	1.80	-28.58	4~8
East of lake	73.94	0.81	74.75	105.51	51.10	51.29	1.17	1.44	-32.21	4~8
Zheng-Xi-Yu area	62.16	1.16	63.32	114.77	28.15	83.63	1.79	1.20	-50.96	1~9

Plain along Huangpujian and the sea	92.08	0.91	92.99	145.98	43.24	93.30	7.22	2.22	-53.00	1~12
Shaoxi brook	9.18	0.16	9.34	12.30	9.84	1.58	0.11	0.77	-2.96	7~10
Hangzhou-Jiaxing_huzhou plain area	32.53	0.56	33.09	41.38	29.18	8.38	1.28	2.54	-8.29	1~12
Total			367.31	541.77	220.52				-176.0	

In terms of the results of forecast provided by Nanjing Institute of Geography and Limnology, Chinese Academy of Science (1993), the deficiency of water in 2000 is estimated 149.73×10^8 m^3 (P=50%), 158.78×10^8 m^3 (P=75%) and 176.0×10^8 m^3 (P=95%) respectively.

The period of water shortage in a year is mainly from May to August when the crops grow actively and the demand for water is urgent. In Shanghai, the majority of water is used in industrial production. The situation is severe all the year. If it is to meet the demand for water and mitigate the contradiction between supply and demand, the supply of water must be raised. Under present natural geographic condition, it is impossible to change precipitation and runoff obviously. Therefore the only method to increase water supply is to form a complete hydraulic project and tap the latent power. Meanwhile new hydraulic projects should be constructed. It is forecasted that the water that can be supplied in 2000 is 344.66×10^8 m^3 (P=50%), 354.42×10^8 m^3 (P=75%) and 367.31×10^8 m^3 (P=95%) respectively. The contradiction between water supply and demand is still very grave.

According to the results calculated by Taihu Lake Basin Management Bureau, the total amount of water demand of the Basin in 2000 is 570×10^8 m^3 if the rate of guarantee is 95% during the peak period of water consumption (in 1971 it was a typical year), in which, the demand for water in agriculture is 202×10^8 m^3, in industry, 270×10^8 m^3, in daily living in cities or rural area, 20×10^8 m^3, and in environment, 68×10^8 m^3. However the average annual total water resource is 164.99×10^8 m^3. In 1971 which is a droughty year, it was 80×10^8 m^3 (P=94%), in seriously droughty 1978, only 16×10^8 m^3 (P=98%).

2.2.3.5 Problems Existing between Water Supply and Demand

The major causes resulting in the contradiction between water supply and water demand or water resource shortage can be summerized as follows: (1) small runoff and uneven distribution, (2) no effective control over water in lake, (3) land reclamation for lakes and rivers, (4) degradation of water quality of lake and river, (5) water quality lower reaches affected by tidewater, and (6) rapid increase of water demand and consumption.

2.3 The Features and Causes of Flooding and Drought in Taihu Lake Basin

2.3.1 The features of flooding and drought in Taihu Lake Basin

The water system in Taihu Lake Basin have been treated for many years, it still faces a severe flooding situation. Recently, there are new characteristics as follows:

- In the 1950s, there was 900 mm rainfall in the flooding period, and the water level in Taihu Lake was only 4.0m, nowadays, there was 300-400mm rainfall in the flooding period, but the water level in Taihu Lake goes beyond 3.5m (warning water level in Taihu Lake is 3.5m).
- Within earlier 5 years in the 1990s, there appeared high water level three times, the highest water level in Taihu Lake was 4.79m in 1991, 4.51m in 1993 and 4.32m in 1995.
- In 1991, there was a rainfall with a frequency of 20 years, and a high water level with a frequency of above 50 years have happened。
- In the flooding period, the maximum rising extent of daily water level becomes larger and larger year by year. In 1954, the maximum rising extent of daily water level was only 9cm/d, but in 1991,became 13cm/d, and reached 22cm/d in 1995.
- There is no complete correspondence among rainfall, water situation and flooding.

2.3.2 The causes of flooding and drought in Taihu Lake Basin

(1) Uneven distribution of annual and multiple-year rainfalls

There is an uneven distribution of annual and multiple-year rainfalls in Taihu Lake. The rainfall in June and July largely comes from the weather processes created by intermittent drizzles. In Shanghai, the rainfall in Autumn and September caused by typhoon weather process accounts for 30% and 38% of total annual rainfall. In early and mid-June when intermittent drizzles closes, subtropical high pressure goes north, its ridgelines controls the region of mid- and lower reaches of Yangtze River, the rainfall gradually decreases. Except for the impacts from typhoon, there is an impact from the invasion of cold air, and rainfall increases again.

According to that data from Dongshan monitoring station in Taihu Lake, 1977 is rich-water year, the rainfall reached 1309.4mm, causing disaster of flooding and drought. Only in Suzhou,, flooded areas was above 500 thousand Chinese mu. 1978 is a year with very less intermittent drizzles, so is a low-water year with a rainfall of only 722.6mm, accounting for 1/2 and more than 1977, which is the year with the lowest rainfall since the establishment of New China, also is the most serious drought among three droughts after the liberation of Jiangsu, there were 4.5 million Chinese mu without any harvests, in the meantime, there were about more than 100million Chinese mu cropland in Taihu plain attacked to different extent by drought disaster. In May, 1967, the rainfall was 125.0mm, only 44.6～58.7mm in June and July, 0.1～ 6.5mm in Autumn and

September.

The discrete coefficient of different rainfall monitoring stations (Table 11) increased from the west bank to east bank, the coefficient for Wulou at the southeast bank was 0.0446 lager than Dapu at the northwest bank, and that for land far from the lake was larger than at the bank of the lake, and that at the bank of the lake was larger than the central areas of the lake. Although the difference between them was very small, it still demonstrated the role of Taihu Lake for rainfall regulation, making the multiple-year rainfall nearby the lake was slightly smaller than areas far from the lake. The discrete coefficient of monthly rainfall in Xishan station CV (Table 12) has shown that the multiple-year rainfall is much more larger than annual rainfall. That is to say, since Autumn, the discrete coefficient of monthly rainfall CV obviously rises, indicating an increase in multiple-year rainfall。 The period from Autumn to October is the high water demand one for crop growth, but the monthly rainfall has decreased gradually, furthermore , Autumn is the high evaporation period, the increase in multiple-year rainfall easily caused the drought in the period. Although the discrete coefficient of rainfall CV in June and July was smaller than other months, the monthly rainfall was very large, the uneven rainfall easily caused the flooding and waterlogging disaster.

Table 11 The discrete coefficient of annual rainfall in Taihu Lake, 1954 - 1984

	Yixing	Dapu	Wuxi	Wangting	Wujiang	Xishan	Dapu	Wuxian
Cv	0.1896	0.1650	0.1964	0.1900	0.1996	0.1904		
ΔCv	0.0246		0.0064		0.0092		0.0446	

Table 12 The discrete coefficient of monthly rainfall in Xishan (CV)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Cv	0.6958	0.5718	0.5062	0.4173	0.4688	0.4541	0.5287	0.7303	0.7185	0.8955	0.7350	0.8100	0.1904

The brief data on flooding between 1954 and 1999 shows the relations between uneven distribution of annual and multiple-year rainfall and flooding. The flooding in 1954 was the first big one in this region after the national liberation, the annual average rainfall of the region reached 470 mm. From the calculations by Yangtze River Basin Planning Office and some local government departments, the total amount of flooding reached 21.21 billion m^3, of which the flooding amount in the upper reach of Taihu Lake was 11.64 m^3, the waterlogging amount was 95.7 billion m^3 in the lower reach. The total water discharge in Huangpujinag River was 88.0 billion m^3, the water discharge via other outlets to Yangtze River 10-13 billion m^3, and the water staying in lakes and river networks was about 80 billion m3 or so, and made 7.85million Chinese mu cropland suffered.

The intermittent drizzles in came earlier, lasted longer, and expanded wider, and the temporary and spatial distribution of rainfall was very uneven, the intensity of rainfall was very big. In early June, 1991, subtropical high pressure went north and became stronger, met cold air from northern China areas along the mid-and lower reaches and between Yangtze River and Huai River. The first storm appeared in June 12-19, whose center was in Huxi canal of Jiangsu. Big storm largely appeared in June 12-15, June 30 to July 5. The rainfall reduced from the northwest to the southeast of Taihu lake, concentrating at Danyang city and Jingtan city, the rainfall within 4 days reached 291mm in Jingtan, and within 7days, the average rainfall of the Taihu Lake Basin attained 220 mm, then Jingtan, Changzhou and Wuxi which were in the central areas of precipitation had the rainfall of 330 mm or so, the rainfall frequency to the west of Taihu Lake, was one time 100 years, the flooding going into the Taihu Lake was 20 billion m^3, the water level of Taihu Lake went up greatly from 3.46 m to 4.28 m. The flooding made Changzhou, Wuxi suffer from serious disaster. More serious was the earlier rising of river water level, and the added water from the first storm had not subsidised, the second big storm came fast again, making the regulation capacity of the second rainfall in July flooding period decrease greatly. In early July, the second storm center was still at the areas west to Taihu Lake (Jingtan, Luoshe), the 3-day maximum rainfall was 377mm in Jingtan, the average rainfall in the region was 250 mm; the rainfall frequency was one time 100-200 years, making the water level of Taihu Lake rising greatly, then the water level of related water networks go over the hgihest level of the history, in July 16, the water level in Taihu Lake reached 4.78m. The suffered areas of the region was 51.08 million Chinese, mu, of which serious disaster areas were 1.3502 million Chinese mu, also concentrating in the Huxi canal areas of Jiangsu, Changzhou and Wuxi had very serious disaster. The suffered areas produced by continuous storms were (1)Taohu area, including Jingtan, Wujing,Changzhou, Liyang, Yixing and Danyang ; (2] lowland in Wuxi city, including Wuxi county, Qingyang, Changshou ; (3) the areas along the Yangtze River, including Zhangjiagang, Jiangying ; (4] Suzhou, Wuxian, Kunshan, Qingpu and Jingshan inYang-cheng-ding-mao area; (5)some part of Jiaxing, Huzhou and Changhxing. The disaster caused big economic losses. In this flooding, the irrigation facilities in Taihu Lake and other medium and small-size lakes played an important role in reducing flooding. The direct economic loss in the flooding was 10.6 billion RMB yuan, and indirect economic loss was 20.0 billion RMB yuan.

The current waterhead of Taihu Lake comes from Jingxi water system west to the Lake and Shaoxi water system from west Zhejiang. The water amount into the lake depends on the runoff after the rainfall. In comparison with flooding in 1991and 1954, Table 13 shows the specific rainfall and produced water amount in the west areas of Taihu Lake and the area of Zhejinag privince. Obviously, in the west areas of Taihu Lake, the maximum rainfall for one day, 3-day, 30-day, 60-day and 90-days were greater than the maximum rainfall, also greater than the specific rainfall in the same period of maximum intermittent drizzles in 1954 since the nation's liberation. Then the maximum rainfall for 3-day and 30-day in the west area of the lake is the infrequent record, one time greater than that in the same period in 1954. In contrast, in the west areas of Zhejinang, the maximum specific rainfall for one day, 3-day, 60-day and 90-days were one time greater than that in the same period.

The temporary and spatial distribution of rainfall in 1954 was comparatively even, characterized by continuous drizzles, but in 1991, there were two big storms, concentrating in Huxi canal areas of Jiangsu, making the suburban areas of Changzhou, Wuxi suffered from serious water disaster.

There were four features for the temporary and spatial distribution of rainfall in 1991: ▪ 1 ▪ the rainfall for 30-day and 60-day relatively concentrated in the region ; ▪ 2 ▪ the rainfall in Suzhou-Wuxi-Changzhou region particularly concentrated ; ▪ 3 ▪ the rainfall in the upper areas of the west part of the lake particularly concentrated ; ▪ 4 ▪ there was little rainfall in the southern areas of the region.

From Table 13, there was a difference in the water production amount between 1991and 1954 : In May 21-July16, 1991, the water production amount within 57days was 48.14 billion m3 ; in contrast, from May to July, in 1954, the water production amount in the west areas of the lake within 92 days was 37.01 billion m3, making the flooding in the west areas of the lake in Jiangsu much more serious in 1991 than in 1954. In contrast, in the west part of Zhejinag, the water production amount from May 21 to July 16 ,1991, was 7.81 billion m3 ; but the water production amount in from May to July ,1954, was 40.70 billion m3, the water production amount in 1991was much less than in 1954, which is why the water disaster is more slight in the west part of Zhejiang.

Referring to Taihu Lake Basin, the rainfall and the water production amount in 1991 were all less than in 1954, the maximum runoff in Yangtze River also was 2/3 of that in 1954, moreover, in Tianmushan areas of west Zhejiang, there was no storm to happen. In a word, the flooding and waterlogging in 1991 was not more serious than in 1954, the disaster has largely come from rainwater logging.

Table 13 The characteristics of rainfall in the flooding periods in 1991 and 1954

	Area in each region (km^2)	The eigenvalue of rainfall (mm)										Water production amount (billion m^3)	
		One day (maximum)		3-day (maximum)		30-day (maximum)		60-day (maximum)		90-day (maximum)			
		1991	1954	1991	1954	1991	1954	1991	1954	1991	1954	1991	1954
Wwest part of Taihu lake	7307	111	83	247	110	707	364	859	615	908	831	48.14	37.01
West part of Zhejiang	5945	59	115	100	177	374	506	488	906	643	1237	17.81	40.70

(2) The inflow is larger than outflow in Taihu Lake

Taihu Lake is the center for the regulation of flooding in Taihu Lake Basin. The bottomland surrounding Taihu Lake is the zone of water network, having inter-connected rivers and lakes, and the slope of water networks is only 0.3/10000, the water flowing is very slow. When the water level in Taihu Lake rises, the water levels of water networks connected with Taihu Lake are also elevated, which determined the water level of the rivers and lakes within Taihu Lake Basin, and the capacity to store up and discharge water. In the flooding period of 1991, the water level in the bottom of the lake was high, and the inflow from the upper reach of the west Taihu Lake was large and fast, making the water level in the lake go beyond the highest point of the past。 In May 1, the water level in Xishan Station of Taihu Lake was 3.52 m, 0.43 m higher than that in 1954. Before the advent of the first storm, further reached 3.46m in June 11, only 4 cm lower than warning water level of 3.50 m. in the meantime, the water level went up very fast. In mid-June, 1991, after the first storm, the water level rocketed up in June 19 to 4.28 m, close to that of the same term in 1954. And the second storm closed, the water level got to 4.79 m in July 15 , which was the highest water level, and kept the is level on July 16, 14 cm higher than the highest record of in 1954,and the presence date advanced 10 days. In 1991, two storms all made the water level of the lake went up by 0.8m or so.

Due to high-speed economic development, urban flooding protection facilities and rural embarkments also developed greatly. There often built dikes and flooding-discharging stations in swales, the powers for discharging waterlogging uprushed, currently, power capacity for discharging waterlogging has exceeded 7000 m^3/s.

The capacity for inner-discharging and outside-discharging has not matched, the capacity to discharge water from watercourses to rivers and sea is only half of that from diking areas to watercourses, the capacity to discharge water from watercourses to river and sea is less than the capacity to discharge inner-waterlogging.

There are contradictions for discharging flooding and waterlogging in the lower reach of Taihu Lake. The existing discharging engineering has not played greater role in discharging flooding from the lake. Taipu River, Wangyu River are all ones that need receive both flooding from Taihu Lake and regional waterlogging, because the ten treatment engineering for Taihu Lake Basin has not finished, so logging water from flooding would first occupy two rivers, making the capacity of Taihu Lake to discharge flooding trail regional capacity to discharge waterlogging, and not effectively reducing the flood peak in Taihu Lake. For example, the logging water from Wujing, Yangcheng and Wuxi approached east to Wangyu River, but the control line at the east bank of Wangyu Riverhas been built up and acted well, logging water not going intoYangcheng areas, staying in Wangyu River, occupying the ways for aterlogging discharging of Taihu Lake ; in the same time, the logging water from Hangzhou, Jiaxing and Huzhou went north into Taipu River, and the lower reach of Yonggao River, the two main discharging rivers had not played role in discharging flooding water from Taihu Lake, making the water level in Taihu Lake rose up to 4.32m. Just because the interactions of human and natural factors; made Taihu lake become a "closed lake" in big storm periods. Sometimes, the amount of outflow from the lake was far less than the amount of inflow, leading to a very high water level of the lake, and seriously threatening the life security of the region and the operation of the economy.

(3)The landform in Taihu Lake Basin

The land reform in the lake basin was changed because of reclamation (including enclosing the lake and blocking up the water flow), reducing the capacity to regulate the level and the storage of water, elevating the water level of the lake and increasing the burden on preventing flooding and discharging waterlogging : due to the mud deposition and the changes of water system, an emphasis on the principle of "grain first" as well as other anthropogenic reasons, the speed and size of the lake reclamation after the liberation increased unprecedentedly. After the setting up of new China, the lowland and the shallow beaches with the height of the areas located in the lower reach of the lake was lower than 4m (Wusong Basis) were largely built on dikes. According to the statistical data in 1990, currently, there are about 7000 dikes in the Taihu Lake, having a total area of 11000 km^2, of which there are 498 dikes with a total area of 528.55 km^2 within the period of 1949—1985 (Table 14) about 380 dikes with an area of 362 km^2 have been approbated by the local departmentsof Jiangsu, Zhejinag aand Shanghai), accounting for 13.6% of the total diked areas of 3884.87 km^2, there is an avarage reduction of 14.69 km^2 per year because of enclosing the lake. The lake number for enclosing has reached 239, 33.8% of the total lakes after the set up of the nation. The number of lakes disappearred due to enclosing 165, 23.3% of the total lakes in the region. The enclosing of lakes has directly reduced the capacity to regulating the water level and storage volume of the lakes.

Taihu Lake is usually called as " water country and inundated area," and is one of the regions having the most lakes in mid- and lower reached of Yangtze River. The setup of dikes in the region is a gradual process from 1950 to 1970 (Table 14) , getting to the peak point in the 1970s. In the 1980s, the activities for diking tobogganed, the tendency to compete for land with lakes was reduced. To analyze the impacts of enclosing on environment, we can divide the whole region into 6 areas as Taihu lake, Yaoge, Hangzhou-Jiaxing-Huzhou, Jiashan-Pinghu, and Dianmaoand Yangcheng.

In this six lakes, within 36 years from the setup of the nation to 1985, there built 218 dikes, totalling 299.18 km^2 (Table 15), accounting for 43% of dikes built in the region, and 56.6% of the total built dike area in the region. We can divide these dikes into 4 classes according to the difference of their sizes in these 6 lakes (Table 16) in terms of dike number, there are 76 dikes with an area below 0.5 km^2, accounting for 34.8% of total dikes, and 7.7% of the total dike area in 6 lakes ; there are 3 dikes with an area above10 km^2, accounting for 1.4% of the total dike number, and 17.8% of the total dike area in the 6 lakes. In many very small-size lake wetland, the dikes with an area of below 0.5 km^2 dominated. From the statistical data of dike classification, in a microscopic viewpoint, the built dikes in the region are not interconnected, and middle and small-size dikes dominates in the region, in contrast, the regions of Dongtinghu Lake and Poyanghu Lake in the middle reach of Yangtze River, large and mid-size dikes dominates. This has shown that, the research on the enclosing in Taihu Lake Basin and their strategies should put an focus on large-size and mid-size lakes.

When dikes built, the areas within the dikes can not discharge flooding and need a water pump to make logging water go outisde., which increased both the cost of production and the burden of flooding prevention in areas of the lower reach of the region. Especially in some lowland, the fields whose height is lower than the avarage water level of lakes outside dikes are easily threatened by waterlogging. In the areas of lower reach of the Taihu Lake and Hangzhou-Jiaxing-Huzhou region, the groundwater is typically 0.5m deep, some only 0.3m, when heavy rain, waterlogging within dikes would occur. From late April to mid-November of each year, waterlogging is in urgent need and the electric power for discharging must be 600-750kWh/ha, 8-12 times higher than typical non-diking fields.

The diking in some lowland made some river work and lakes enclosed and become inner ports and inner lakes, although there existed water, the capacity to regulate water amount in the region lost. According to the calculation, from 1964 to 1990, the water level outside the region reduced by 800 km^2 (the area reclaimed to be cropland is 500 km^2, the water level within the dikes increased by 300 km^2), an equivalent of 1/3 of Taihu Lake. The reduced amount in the west part of the lake was biggest, occupying about half of that in the 1960s. In addition, the total area of reclamation after the liberation is 160 km^2, reducing 0.32 billion m^3 of water storage and weakening the functioning of Taihu Lake as a central regulator of flooding. The reclamation in wetlands will elevate the flooding water level of the lake. According to the calculation, the water level in Taihu Lake has been elevated by 9-14cm due to lake reclamation after the liberation, the Yaoge part in the west Taihu Lake had 15-20cm elevation of water level. This ahs shown that enclosure in lakes will lead to the rapid elevation of water level, and lasting time of high water level are prolonged and finally increase the pressure of flooding prevention in the region.

Building embarkments had changed the landform of Taihu Lake Basin, disturbed the original water systems, making the water situation in some parts of Taihu Lake changed, increasing the burden of flooding prevention and waterlogging discharging. The changes of water situation caused by lake reclamation is very clear. For example, the east part of Taihu Lake, historically, is the main offal for flooding discharging and the throat of drainage. According to the investigations on the scale of 1:50000 relief map, there was an area of 265 km^2 in the east part of Taihu Lake, the breadth of water section nearby Yaojiazhuang village of Tauhu Lake was 6km, later on, because of lasting lake reclamation and mud deposition, the area of water had reduced to 163 km^2, the breadth of water section nearby Yaojiazhuang village was only 0.2 km. In the early 1950s, there were 84 various outlets and ditches in the east part of Yaihu Lake, more than 30 years after the reclamation of lakes and rivers, there existed only more than 10. The Guajin port, one of the main offals of water discharge, its runoff gradually diminished year by year, having a negative relation to the expanding of reclamation since the 1950s. Taking the average runoff in the 1950s as a basis, there are a diminishing percentage of 29.4% and 44.3% in the 1960s and the 1970s. If we compare the maximum water flux in different years, we also get obviously similar results. For example, the maximum water in the 1950s was 172.0m^3/s (June 28;1954) , and 111.0m^3/s in 1957, in the 1960s, there never existed an flux of above 100.0m^3/s. The year 1983 was rarely rich-rainwater one with a maximum flux of 67.9m^3/s. In 1957, the water discharging amount in the east part of Taihu Lake was 88% of the total of Taihu Lake, but dropped to 44% in 1980. The changes in the ratio of water discharging amounts in the two parts of Taihu Lake, has certainly shown the important causes for the changes in water fluxes.

Table 14 Statistical data on reclamation dynamics by different zones

Name of lakes	1950s		1960s		1970s		1980s		Total	
	Number of dikes	Area (km^2)	Number of dikes	Area (km^2)	Number of dikes	Area (km^2)	Number of dikes	Area (km^2)	Number of dikes	Area (km^2)
Taihu Lake Zone	7	9.23	39	67.73	68	82.16	2	1.05	116	160.17
Yaoge Lake Zone	3	2.01	28	28.63	91	147.32	4	4.18	126	182.14
Hangzhou-Jiaxing-Huzhou Zone	2	0.37	14	10.76	54	24.94	6	2.76	76	38.83
Dianmao Zone	1	0.45	26	17.36	84	58.63	5	2.05	116	78.49
YangchengZone	2	0.94	8	28.08	24	19.05	2	0.30	36	48.37
Jiashan-Pinghu Zone	1	0.35	10	4.41	13	8.91	4	6.88	28	20.55
Total	16	13.35	125	156.97	334	341.01	23	17.22	498	528.55

Table 15 The dynamics of reclamation in large or middle-size lakes in Taihu Lake Basin

Names of lakes	lake size (km^2)	1950s			1960s		
		Number of dikes	The area of built dikes (km^2)	Conserved lake area(km^2)	Number of dikes	The area of built dikes (km^2)	Conserved lake area(km^2)
Taihu Lake	2587.98	7	9.23	2573.75	39	67.73	2511.02
Gehu Lake	253.78	-	-	253.78	19	22.71	231.07
Yang cheng Lake	122.87	1	0.10	122.77	-	-	122.77
Yaohu Lake	111.43	-	-	111.43	1	0.65	110.78
Dingshanhu Lake	65.32	-	-	65.32	1	0.80	64.52
Chenghu Lake	44.42	-	-	44.42	-	-	44.42
Total	3185.80	8	9.33	3176.47	60	91.89	3084.58

Names of lakes	lake size (km^2)	1980s					Total	
		The area of built dikes (km^2)	Conserved lake area(km^2)	The number of built dikes	The area of built dikes (km^2)	Conserved lake area(km^2)	The number of built dikes	The area of built dikes (km^2)
Taihu Lake	2587.98	68	2428.86	2	1.05	2338	116	160.17
Gehu Lake	253.78	49	146.37	-	-	146.37	68	107.41
Yang cheng Lake	122.87	5	119.13	1	0.10	119.03	7	3.84
Yaohu Lake	111.43	19	90.47	2	1.50	88.97	22	22.46
Dingshanhu Lake	65.32	-	64.52	1	0.72	63.80	2	1.52
Chenghu Lake	44.42	3	40.64	-	-	40.64	3	3.78
Total	3185.80	144	2889.99	6	3.37	2886.62	218	299.18

The embarkments and enclosure have not only changed the water situation of some sections of large or middle-size lakes, but also exerted an obvious impacts on water situation of various wetlands. For example, the reclamation in 1976 had made the five outflowing waterways connected through Zhangwandang marsh on the lower reach of the Lake, originally having an area of 1.07 km^2, blocked up. The water from the upper reach of the lake via this marsh originally discharged water northly, because of this blocking-up, the water inversely flowed south, and elevated the water level of North Jiaxing areas in the upper reach of the lake. According to investigations from local governments, the elevation of water level was 0.2m and the characteristics of water situation in Taihu Lake Basin in comparison with that in the 1950s were fast occurrence, fast elevation of water level, long stagnation time and slow water withdrawing and large suffered area. The embarkments have led to the changes in water situation and the shape of lakes, which are one of the important reasons for the appearance of the above characteristics.

Table 16 The Statistical data on the classification of dikes in large and middle-size lakes

Names of lakes	>10 km^2 dikes		1-10 km^2 dikes		0.5-1.0 km^2		0.1-0.5 km^2	
	The number of built dikes	Areas (km^2)	The number of built dikes	Areas (km^2)	The number of built dikes	Areas (km^2)	The number of built dikes	Areas (km^2)
Taihu Lake	2	33.06	37	94.24	30	21.59	47	11.28
Gehu Lake	1	20.33	25	63.63	19	15.12	23	8.33
Yang cheng Lake			1	1.50	4	1.13	2	1.21
Yaohu Lake			8	13.64	11	7.91	3	1.91
Dingshanhu Lake					2	1.52		
Chenghu Lake			1	2.68	1	0.62	1	0.48
Total	3	53.39	72	175.69	67	47.89	76	23.21

Table 17 The water flux of different years in Guajin port in the east Taihu Lake

Period	Average flux (m^3/s)	Maximum flux (m^3/s)	Notes
1950s	25.5	172.0	1954 - 1959
1960s	18.0	90.8	
1970s	13.7	89.9	

(4) The structure of land surface has changed, and considerable permeable ground turned into impermeable one

According to some investigations in U.S., when impermeable ground accounts for 12% of the total land, and average flooding flux is17.8 m^3/s, the confluent time of flooding is 3.5 h. In contrast, when impermeable ground accounts for 40%, and average flooding flux increases to 57.8m3/s, the confluent time of flooding decreases to 0.4h. With rapid increasing of residential areas and roads, the total area of cities, industrial and transportation land increases proportionally, for example, in the plain areas of South Jiangsu accounts for 8.5% of the total land, about 15% in Shanghai, and it was only 4.5% in Hangzhou-Jiaxinga-Huzhou region (Table 18).

Table 18 The percentage of industrial and transportation land in Taihu Lake Basin

Zones	Pudong	Puxi	South Jiangsu	Hangzhou-Jiaxinga-Huzhou region	Hilly land
percentage (%)	17.0	13.6	8.5	4.5	1.8

With the impermeability of urban ground increases, the ground runoff coefficient coorespondently becomes large, in the flooding period of 1991, the runoff coefficient of the Wujing-Yangcheng-Wuxi region which has more towns was 0.758 ; But the runoff coefficient in the areas along Taihu Lake 0.664. In addition, the area of some natural waterbodies largely decreased because some urban construction made the original rivers and lakes filled and leveled up. For example, In Changzhou, due to urban expansion, half of small ponds have been filled up, the area of rivers in the urban areas is only 7.36 km^2, largely weakening the urban capacity to regulate the water storage. So without certain irrigation facilities, urbanization would surely lead to an increasing runoff coefficient with the same rainfall condition, further cause water disaster.

3. The Quality of Water Resources and the Status Quo of Aquatic Environment

3.1 Pollution sources

Pollution sources include wastewater discharge produced by human daily life and various activities of production. In terms of lines, pollution sources consist of industry, domestic, stock and fowl culture, aquaculture, etc.. According to the statistical data in 1994, the total discharge of wastewater and sewage (TDWS) in basin came up to 3,200 million ton per annum (now 3,500 million); chemical oxygen demand (COD_{Cr}), 282,404 ton; total nitrogen (TN), 79,522 ton; total phosphorus (TP), 5,660 ton (Table 19). The TDWS in the basin accounts for 1/10 of national TDWS, 1/3 of that in Yangtse River valley. Wastewater discharge per unit area reached to 109,000 ton per annum. There were 80% of wastewater and sewage untreated, or the treatment did not accord with the effluent standard. The discharge intensity of wastewater and sewage was higher than ten times of that in Huaihe River valley.

The chemical fertilizer applied in the basin is 2-3 million ton annually, 100-200 kg per mu and pesticide, 50-80 thousand tons, 2.8 kg per mu. The chemical fertilizer efficiency is less than 50%. Nearly a half of chemical fertilizer flows into waters early or late. With the urbanization in the basin, the great increase in domestic garbage of inhabitants and the development of aquaculture, tourism and shipping etc. the deterioration of water environment is aggravated due to no favorable control and management on pollution.

3.1.1 Regional Load of Industrial and Domestic Pollution in Cities and Towns

The sewage in Shanghai is 5.1 million ton per day (in which industrial wastewater is 4 million ton, domestic sewage, about 1.1 million ton). The sewage directly discharged into Huangpujiang River and its tributaries is 3.22 million ton or so per day, the sewage discharged into Yangtze River estuary, 870 thousand ton. The eligibility of treatment is just 17%. The average flow for many years in Mishidu station of Huangpujiang River is merely 316 m^3/s. The rate of clean water to wastewater is 6.5:1. Huangpujiang River has basically lost its self-purification. Suzhouhe River, the largest tributary of Huangpujiang River, is also the important channel receiving pollutants from Shanghai City. Every day the pollutants discharged into Huangpujiang River via Suzhouhe River amount to about 1/3 of total pollutant amount in Huangpujiang River. The dissolved oxygen (DO), one of the major water quality indexes, is 2 mg/l averagely in Huangpujiang River, merely meeting the national standard grade V, 1.4 mg/l averagely in Suzhouhe River, not meeting the national standard grade V; COD, another major water quality index, 8.03 mg/l averagely in Huangpujiang River, the maximum, 58.4 mg/l, while 16.9 mg/l averagely in Suzhouhe River, the highest value 62.2 mg/l. According to the statistics, the COD discharged into Yangtze River from Huangpujiang River per year is 50.8 thousand ton, Hg, 3.0 ton, Cu, 238.9 ton, Zn, 1,300 ton, Al, 249.0 ton, Cd, 1.80 ton, oils, 0.483 ton.

Table 19 The total discharge of pollutants in Taihu Lake area (1994)

Pollution sources		Wastewater amount (10^4 t/a)	COD_{Cr} (t/a)	CR on COD_{Cr} (%)	TN (t/a)	CR on TN (%)	TP (t/a)	CR on TP (%)
Industrial wastewater in major trades		53901	111061		12544	15.8	591	10.4
Domestic sewage		32290	119029		19948	25.1	3394	70.5
Non-point sources in countryside	Farmland loss and erosion	128373			18355	23	164	2.9
	Scattered inhabitants	15671	11377		1896	2.4	433	7.65
	Stock and fowl culture	1203	16761		9591	12.0	255	4.5
	Sum	145247	28138		29842		852	
Fisheries		83774			13195	16.6	533	9.4
Domestic pollution along lakeland		216	417		21	0.03	3	0.05
Precipitation on lake surface		3341	23595		2760	3.4	60	1.06
Falling dust					421	0.5	33	0.58
Ships			164		22	0.03	2	0.03
Water loss and soil erosion					800	1	192	3.39
Total		318769	282404		79552		5660	

The total area of 10 counties in the suburbs of Shanghai is 5,800 km^2. The factories and enterprises distributed on these counties discharge 1.98 million-ton industrial wastewater. That treated and drained into Yangtze River accounts for 14.7% and the rest is discharged into river channels on the spot. Dwellers, livestock and fishery products are first victimized. Because river waters are irrigating sources, the farmlands, soils and crops are also subjected to contamination, among which the pollution of water near to the suburbs is more serious. The industry on the outskirts is made up of lines such as metallurgical industry, chemical industry, pharmacy, pesticides, tannery, bleaching and dyeing, electroplating, instrument and meter, slaughtering, etc.. The main toxicants entering the surroundings along with industrial wastewater are Hg and Cd, the next ones are Cr, Pb and phenol. For an instance, in Haoqiaogang of Baoshan district, Shanghai, the maximum concentration of Hg is 2.50 mg/l; in Mayibang, the concentration of Cd is meanly 0.605 mg/l; the maximum Cd content in river bottom sediment is 113.25 mg/l. More than 50 chemical plants and village and township enterprises are converged on the Taopu Industrial Zone situated in Jiading district, discharging 35 thousand ton of wastewater containing Hg, Cd, Pb and sundry organic matters as well every day. For Songjiang, Jinshan and Qingpu County in the remote suburbs, the runoff is more affluent, so most river channels have better self-purification capacity and the water pollution is lighter. The industrial wastewater in Jinshan County is 9,500 ton every day, in Songjiang and Qingpu County, both not more than 50 thousand t/d, while in Baoshan district on the outskirts, 95 thousand t/d, in Shanghai County, 135 thousand t/d.

In 1989, the total domestic sewage discharge amount in Changzhou, Wuxi and Suzhou City was about 5,617 million ton, which imposed direct impact on the rivers in the cities resulting in deterioration of water quality. The population in Changzhou City and its suburbs is around 658 thousand. The domestic sewage discharge was 1.9 million t/a, and the COD discharge, 5,796 t/a. The population in Wuxi City and its suburbs is 913.2 thousand, the domestic sewage discharge was about 26,953 t/a, and COD, 7,408 t/a. The population in Suzhou City is 886 thousand, the domestic sewage discharge, 17.22 million t/a, COD, 768.2 t/a, BOD, 1,594.4 t/a. The total COD amount in domestic sewage of the three cities was approximately 13,972.2 t/a. The order of sewage discharge by sequence from large to small was Wuxi, Changzhou and Suzhou.

In terms of discharge pollutant amount of lines, the first is chemical industry, the second, textile and printing and dyeing, the third, papermaking, the next by sequence, food, tannery and electroplating industry. By analysis of the pollutant discharge every ten thousand yuan output value, papermaking is 1,673 ton, chemical industry, 1,358 ton, food, 324 ton, tannery, 248 ton, electroplating, 247 ton and textile and printing and dyeing, 174 ton.

Table 20 The discharge of industrial wastewater in Wuxi City (1997)

Indices	Unit	All Cities	Urban district	Jiangyin City	Yixing City	Xishan City
The total discharge of industrial wastewater	10^4 ton	24752	7529	7049	2100	8074
The discharge of industrial wastewater up to standard	10^4 ton	19263	6724	5294	1112	6133

Source: '98 Wuxi statistic yearbook

The domestic sewage of cities and towns is from a variety of washing wastewater of human daily life, in which the contents of N, P and S are high so that it is easy to produce stinking matters under the reaction of anaerobic bacteria. Mostly pH is over 7 and BOD, 100-700 mg/l. In domestic sewage, there are still all kinds of detergents and a small amount of trace metal elements as Zn, Cu, Cr, Pb, etc.. Moreover, there are many sorts of microorganisms. By estimation every milliliter domestic sewage may contain several ten thousand of bacteria, some of which are probably germs or pathogens.

According to the contamination survey data in 1985, the total amount of pollutants discharged into canal network from Changzhou, Wuxi and Suzhou was 238,741.32 ton, in which comprehensive organic pollutants were 233,363.73 ton, dominatingly 97.75% of the total amount; toxicants, 4,346.88 ton, 1.8% of the total; heavy metal, 131.55 ton, 0.06% of the total. The type of water quality pollution was organic pollution. Three indices, COD, phenol and ammonia nitrogen, were most dominant. In total 113 main industrial sources in the 4 cities discharged pollutants into the canal water system. Yearly the total amount of wastewater was 2.663×10^8 ton, COD discharge, 1.21×10^5 ton, BOD, 1,198.3 ton, phenol, 476.3 ton, and ammonia nitrogen, 1,268.2 ton.

Table 21 Data on environment of Suzhou City, 1997 - 1998

	Unit	The whole city	Urban district	Changshu	Zhangjiagang	Taicang	Kunshan	Wuxian	Wujiang
1997									
The discharge of industrial wastewater	10^4 ton	33822	9512	6480	4026	1519	2606	4181	5427
The discharge up to standard	10^4 ton	24385	8059	3965	3448	567	2151	2746	3448
Treated industrial wastewater amount	10^4 ton	28229	5312	3529	11784	1190	963	3590	1860
Treated industrial wastewater amount up to standard	10^4 ton	8786	2739	1756	1390	317	458	1264	863
1998									
The discharge of industrial wastewater	10^4 ton	31283	8531	6155	4046	2052	5879	1044	3576
The discharge up to standard	10^4 ton	25098	7964	4187	3717	1715	3800	768	2947
Treated industrial wastewater amount	10^4 ton	33741	7458	3416	14830	988	2280	1181	3588
Treated industrial wastewater amount up to standard	10^4 ton	11042	3030	1720	1818	729	1360	482	1903

Source: the statistic yearbook in Suzhou in 1998, 1999

Table 22 Data on environment of Shanghai (1996-1998)

Year	1996	1997	1998
The eligibility rate of drinking water (%)	89.01	83.33	92.38
The eligibility rate of city surface water quality (%)	88.89	83.33	92.9
The eligibility rate of industrial wastewater discharge (%)	87.4	86.6	88.2
The treatment rate of municipal sewage (%)	39.65	39.87	53.29
The discharge of industrial wastewater (10^4 t/d)	364.98	273.76	246.63

The discharge up to standard	264.23	237.17	217.41
The discharge pollutants of industrial wastewater (Kg/d)			
Cd and its inorganic compound	0.49	0.05	0.11
Cr^{6+} compound	43.64	13.56	5.42
As and its compound	18.44	11.92	18.88
Pb and its inorganic compound	26.58	4.68	4.6
Cyanide	278.99	79.53	45.53
Oils	19517	9814	7959

Source: the statistic yearbook of Shanghai in 1999

Table 23 The wastewater discharge in Jiaxing City, 1997 - 1998

	1997							
	Unit	The whole city	Urban district	Jiashan	Pinghu	Haining	Haiyan	Tongxiang
The industrial wastewater discharge	10^4 ton	10506.19	2944.58	1009.79	1244.28	1590.35	2155.78	1212.27
The treated industrial wastewater discharge	10^4 ton	6542.53	2835	505.6	1163.48	592.85	914.81	486.86
Up to the discharge standard	10^4 ton	5182.98	2011.65	374.45	902.73	883.09	424.08	570.35
Treated wastewater up to standard	10^4 ton	2383.2	1295.53	154.58	922.6	112.62	0.55	186.69
	1998							
	Unit	The whole city	Urban district	Jiashan	Pinghu	Haining	Haiyan	Tongxiang
The industrial wastewater discharge	10^4 ton	11523.5	3908.33	1520.96	1345.87	1453.34	1384.99	1910.01
The treated industrial wastewater discharge	10^4 ton	7978.28	2582.63	851.94	1308.23	719.1	1174.19	1342.18
Up to the discharge standard	10^4 ton	8315.01	2845.47	932.89	1080.15	1053.39	775.31	1627.8
Treated wastewater up to standard	10^4 ton	4768.22	1187.34	773	763.35	290.7	677.23	1076.6

Data source: the statistic yearbook of Jiaxing in 1998, 1999

Table 24 Data on environment of Huzhou, 1990 - 1997

	The situations of the whole city						
	Unit	1990	1993	1994	1995	1996	1997
The total industrial wastewater discharge	10^4 ton	8326	7001	6821	5519	5338	9641

The industrial wastewater discharge up to standard	10^4 ton	6196	3102	3397	2944	3002	3760
The treated industrial wastewater amount	10^4 ton	2078			3048	3596	5113
The treated industrial wastewater amount up to standard	10^4 ton	1003	420	640	724	962	1212
Urban district							
	Unit	1990	1993	1994	1995	1996	1997
The total industrial wastewater discharge	10^4 ton	3570	3198	2882	2836	2628	3024
The industrial wastewater discharge up to standard	10^4 ton	2818	1956	2106	2077	2250	2407
The treated industrial wastewater amount	10^4 ton	604			1410	2085	1881
The treated industrial wastewater amount up to standard	10^4 ton	514	314	342	340	497	811
Treatment ability for new projects accomplished in 1997							
Treating wastewater	t/d	The whole city	101478	Urban district	1478	Changxing County	100000

Source: the statistic yearbook in 1998

3.1.2 Pollution load of lakes

There are 118 factories and mines along Taihu Lake in a scope of 5 km. The total wastewater discharge in 1987 was 33,826 thousand tons. Sorted by industry, the chemical industry had the largest wastewater discharge, accounting for 54.43% of the total wastewater discharge; the next was papermaking, textile, printing and dyeing. There are 20 enterprises in which each one's total pollutant loading amount in equivalent standard of main pollutants (COD_{Cr}, BOD_5, Cr^{6+}, volatile phenol, cyanide, sulfide, SS) is more than 1,000 ton. As regards to the pollutant load in equivalent standard of enterprises, Xuelang mining plant in Wuxi was the most, Changxing tannery plant in Zhejiang province was the second.

Table 25 Data on environment of Hangzhou, 1997

	unit	All cities	Urban district
The total industrial wastewater discharge	10^4 ton	34665	15891
In the drained industrial wastewater:			
Directly drained into rivers, lakes and reservoirs etc.	10^4 ton	13571	4386
The industrial wastewater discharge up to standard	10^4 ton	16362	12480
Industrial pollutants in drained industrial wastewater			
Hg	Kg	60	40
Cd	Kg	170	120
Cr^{6+}	Kg	5590	900
Pb	Kg	17340	6190
As	Kg	1590	1290

Volatile phenol	Kg	11150	7070
Chloride	Kg	5350	2050
Petroleum	Ton	832	746
COD	Ton	122399	36605
Suspended matter	Ton	42445	18135
Sulfide	Ton	175	57
The eligibility rate of industrial wastewater discharge	%	47.2	78.5
The eligibility rate of treated industrial wastewater discharge	%	34.9	62.8
The treatment rate of industrial wastewater	%	77.9	93.7
The reclamation rate of industrial wastewater	%	44	66
The normal operating rate of treatment equipment for industrial wastewater	%	92.7	87.7

Source: Statistic yearbook of Hangzhou in 1998

The population along Taihu Lake is about 1,857 thousand, livestock, 879.4 thousand, fowl, 4,775.2 thousand. N, P and COD_{Cr} produced by village dwellers along the lake are 6,778.05 t/a, 677.80 t/a and 51,513.18 t/a, those excreted by stock and fowl are 5,931.6 t/a, 1,350.3 t/a and 11,691.3 t/a, respectively.

The number of plants adjacent to Dianshanhu Lake is 60. The total wastewater discharge is 8,150 thousand ton, 31 plants and 6 scenic spots and touring facilities are under the administration of Shanghai City, whose yearly wastewater discharge is 1,400 thousand ton, in which COD_{Cr}, 445 ton, BOD_5, 102.9 ton, NH_3-N, 7.68 ton, TN, 5.809 ton, TP, 1.003 ton. Those enterprises under the administration of Jiangsu discharge wastewater 6,750 thousand yearly, in which COD_{Cr}, 2,393.4 ton, BOD_5, 553 ton. Shanghai Hongqi paper mill is on the top in regard to the pollutant load in equivalent standard. In addition, Daguanyuan tavern, Zhujiajiao paper mill and the second steel pipe factory contaminate severely. It is estimated that at present in the pollutant discharge into Dianshanhu Lake yearly BOD_5 was 18,741.6 ton, COD_{Cr}, 29,800.8 ton, NH_3-N, 3,085 ton, TN, 4,939.2 ton, and TP, 352.8 ton.

Table 26 The circumstances of environmental conversation in Changzhou City, 1997

Items	Unit	All cities	Urban district	Liyang	Jintan	Wujin
The total industrial wastewater discharge	10^4 ton	11194	6222	2058	506	2408
The discharge up to standard	10^4 ton	7907	4656	1809	310	1133
The COD discharge in wastewater	Ton	26763	13082	3249	587	9845
The eligibility rate of industrial wastewater discharge	%	70.6	74.8	87.8	61.2	47
The treatment rate of industrial wastewater	%	62.3	60.7	45.1	18	73.9

Source: the statistic yearbook of Changzhou in 1998

3.1.3 Circumstances of Sewage Treatment

The municipal sewage treatment conditions along the Taihu Lake basin are that Shanghai, Jiangsu and Zhejiang have partly constructed sewage treatment plant. Some of the plants and hotels are furnished with sewage treatment equipment.

The industrial wastewater discharge of Shanghai City in 1998 is 2,466.3 thousand t/d. The eligibility for industrial wastewater discharge is 88.20%. The municipal sewage treatment capacity is 1,887 thousand t/d. The treatment rate is 53.29%. The treatment rate of domestic sewage is 22.65%.

Suzhou, Wuxi and Changzhou City in Jiangsu province have constructed sewage treatment plant. 6 municipal sewage treatment plants have been built and put in operation in Suzhou and the total treatment capacity is 102.5 thousand t/d. The plants being built or extended include the sewage treatment plant in the south Suzhou, 25 thousand t/d, and the sewage treatment plant in the north Suzhou, 20 thousand t/d. In Singapore Industrial Zone in Suzhou the capasity of the sewage treatment plant is 100 thousand t/d. In Wuxi City, one sewage treatment plant has been built, possessing treatment capacity 100 thousand t/d. At the same time, this plant is being expanded and will have another capacity of 100 thousand t/d. Some other sewage treatment plants are being built, including Mashan district sewage treatment plant, treatment capacity 10 thousand t/d, Qianzhou Town sewage treatment plant, 10 thousand t/d treatment capacity. Changzhou City has built 2 sewage treatment plants, each capacity 5,000 ton treatment capacity, being expanded 5,000 t/d respectively. The sewage treatment plant being built in the north Changzhou aims at treatment capacity 50 thousand t/d.

Hangzhou City, Zhejiang province, has constructed 4 sewage treatment plants, daily treatment capacity (primary treatment) being 400 thousand ton. Simultaneously, they are being expanded 200 thousand t/d. After expansion, the sewage treatment plant has 400 thousand t/d secondary treatment capacity and 200 thousand t/d primary treatment capacity, adding up to 600 thousand ton. The operation fees of the above built sewage treatment plants are from municipal maintenance fees and partly from the paid charge for use of discharge pollutant facilities.

3.2 Water Quality and the Present Situation of Water Environment

So far as the water quality in the catchement is not well, except that in Zhejiang province, the separate reservoirs in Tianmushan district has grade-I water quality and east and west Tiaoxi River has relatively good water quality. The water quality of Taipuhe River and Wangyuhe River (the two main river courses) and the rivers surrounding Taihu Lake are very bad. The eutrophication in lakes is serious. According to the assessment of the water quality of Taihu catchement in 1992 promulgated by Water Resources Conservation Councils of Taihu Basin and GB3838-88 environmental quality standard for water, the assessment results on the main river courses, lakes and reservoirs are narrated as follow respectively.

3.2.1 The Water Quality of Different Pollution Section of River Courses

The total length of river courses evaluated for water quality is 1,155.7 km, of which Jiangsu part is 341.0 km, Zhejiang part, 496.3 km, and Shanghai part, 318.4 km. The evaluation is conducted in the light of three different phases as flood season, no flood season, the whole year. In the whole region the river reaches whose water quality is worse than V grade in three phases are the reaches of Jinghang canal in the south of Yangtze River, including Wuxi, Xushuguan, Fengqiao, Suzhou, 54.0 km in length, Tangqi Bridge to Gujiaqiao Bridge reach, 61.5 km long, Huacao to Zhejiang Road Bridge reach in Suzhouhe River, 26.0 km long, Nanxiang of Yunzaobang to Wusong Bridge reach, 25.5 km long, and Qilu No. 9 Bridge reach of Dianpuhe River, 14.9 km in length. The length sum of reaches is 181.9 km, which is 15.7% of the total river length being evaluated, increasing 7.0% than that in 1991.

The reaches whose water quality is above V-grade in three phases are Dantu reach in the Canal, 10.0 km, Qishuyan reach in Changzhou, 24.0 km, Luoshe reach, 10.0 km, Huangdu reach in Suzhou, 8.2 km, Nanshi-Yangpu reach of Huangpujiang River, 24.9 km, and Lujiadu reach of Chuanyanghe in Pudong, 6.7 km, totaling up to 265.7 km, which is 23% of the total length of reaches evaluated.

The total length of the reaches of canal in the south of Yangtze River is 312 km. 299.5 km of reaches are assessed this time. The length of river course for grade-III water quality in the whole year is 51 km, that for grade-IV, 81 km, grade-V, 42 km, that for worse than grade-V, 125.5 km. The water quality in flood season was better than that in no flood season.

The length of evaluated reaches of Taipuhe River is 48 km, in which the water quality in Pingwang reach, 25 km long, is grade-V perennially due to the pollution of volatile phenol. The water quality in Luxu reach is between grade-III and grade-IV as well. The length of evaluated reaches of Suzhouhe River is 45.8 km. There is 11.6 km of reaches whose water quality is grade-V in the whole year, occupying 25.3%. The length of reaches worse than grade-V is 34.2 km, accounting for 74.7%.

East Tiaoxi River has 152.5-km reaches assessed. The reaches with water quality grade-II in the whole year are 28.5 km in length, 18.7%, the reaches with grade-III, 38.7 km long, and grade-IV, 65.0 km, 42.6%. West Tiaoxi river courses evaluated are 197.5 km in length. Grade-II reaches in the whole year are 47.0 km, 23.8%, grade-III, 51.5 km, 38.7%, grade-IV, 65.0 km, 34.7%, and grade-V, 30.5 km, 15.4%.

The evaluated river courses of Wangyuhe River are 3 km, in which the water quality in three phases is all grade-IV. For Licaohe River of Danjin, the evaluated sections are 10 km, grade-IV water quality in the three phases.

The assessed river length of the whole Taihu Lake region is 1,155.7 km. The length of contaminated river whose water quality is worse than grade-IV in flood season, no flood season, the whole year is 786 km, 883 km, 841 km, respectively, accounting for 68%, 77%, 73% of the total evaluated reaches. The pollution is mainly caused by COD, NH3-N and organic pollutants.

3.2.2 Water Quality of Lakes

The area of Taihu Lake is 2,338 km^2. The water quality development of Taihu Lake can be divided into three stages. In the early 1980s, the water quality of Taihu Lake was dominantly grade-II, in the late 1980s, the water quality transition period from grade-II to grade-III and in the middle 1990s, water quality in Taihu Lake mainly grade-III.

Table 27 The grade of water quality for different reaches of some rivers in Taihu basin in 1992

River name	Assessed river length (km)	grade-II		grade-III		grade-IV		grade-V		Worse than grade-V	
		Length	Ratio (%)	Length	Ratio (%)	Length	Ratio (%)	Length	Ratio (%)	Length	Ratio (%)
Canal in the south of Yangtze	299.5			51	17	81	27.1	42	14.0	125.5	41.9
Taipu River	48			10	21	13	27.0	25	52.0		
Huangpujiang River	81.3					56.4	69.4	24.9	30.6		
Suzhouhe River	45.8							11.6	25.3	34.2	74.7
East Tiaoxi River	152.5	28.5	18.7	59.0	38.7	65.0	42.6				
West Tiaoxi River	197.5	47.0	23.8	51.5	26.1	68.5	34.7	30.5	15.4		
Wangyuhe River	3					3	100				
Liuhe river	10					10	100				
Licaohe River in Danjin	10					10	100				

Table 28 The development tendency of organic pollution in Taihu Lake

Water quality situations	1980-1981	1987-1988	1993-1994
Relatively clean (II)	69%	59.4%	15%
Fairly clean (III)	30%	36.6%	70%
Slightly polluted (IV)	1%	3.2%	14%
Heavily polluted (V)		0.8%	1%

(1) In 1980-1981, the water quality in Taihu Lake was primarily grade-II, whose area approximately accounted for 69% of the whole lake. The area of grade-II, III and IV water was 69%, 30%, 1% of the whole lake area, respectively. The grade-III and IV waters were mainly distributed in the entrance of river courses and the waters along the bank east Taihu Lake basin, whose area was around 31% of the whole lake area. The areas whose water quality was comparatively worse were Daxuankou, Dapukou and Lujiangkou, belonging to grade-IV water perennially. The mean concentration of TP in the whole year was 0.064 mg/l; the maximum, 0.330 mg/l, occurring in Lujiangkou in flood season. The average concentration of TN in the whole year was 3.14 mg/l; the maximum value, 9.60 mg/l, appearing in no flood season (Tuoshan). The eutrophic state was dominated by meso-trophication and meso-eutrophication, about 82.8% of the total lake area. Meso-trophication was centered by Pingtaishan, west to Jiapu, east to the center of lake, accounting for 82.8% of the lake area. Meso-eutrophication was mainly between the Southern Taihu Lake and East

and West Mountain and the waters along Wangtingwan and Yixing, 41.3% of the lake area. Eutrophication was mainly situated along the Meilianghu Lake and in partial waters alongshore, 16.8% of the total lake area. Heavy eutrophication (0.4%) was occurring in regions abutting on the inlets of river courses and limited waters of Wulihu Lake.

(2) In 1987-1988, the water quality in Taihu Lake was remarkably different from that in the early 1980s. Grade-II waters decreased about 10%. Grade-III waters increased 25.5%. Grade-IV waters accrued 2.2 times. What's more, the lake witnessed heavily polluted waters (grade-V waters, primarily distributed near to Lujiangkou of Meilianghu Lake and in partial waters of Wulihu Lake, whose area was 0.8% or so of the total lake area). However, in the middle 1990s, the water quality of Taihu Lake worsened apparently. The spatial distribution of grade-II waters reduced to 15% year by year, while that of grade-III waters was extended to 70%, that of grade-IV waters, 14%. Over more than a decade, the over-all water quality of Taihu Lake degraded one grade. In 1987-1988, the meso-trophication of Taihu Lake disappeared. The proportion of meso-eutrophic waters was 59.5%; that of eutrophic waters rocketed to 40%. Eutrophication, whose range was quite vast, was mainly distributed in Wulihu Lake, Meilianghu Lake and the western side of Taihu Lake, accounting for 40% of the whole lake. Meso-eutrophication was chiefly distributed in the central waters of Taihu Lake, whose area was 59.5% of the total lake area.

(3) In 1993-1994, the principal waters of Taihu Lake were grade-III, whose area occupied 70% of the whole lake. The grade-IV waters continued to expand. Heavily contaminated waters (grade-V waters) were mainly in area along Lujiangkou of Meilianghu Lake and partial waters of Wulihu Lake, about 1% of the whole lake. Grade-IV waters were in Meilianghu Lake, the western and southern Taihu Lake region. Grade-III waters were mainly distributed in the center part of lake and east Taihu Lake, 70% or so of the whole lake. Grade-II waters were mainly distributed in Xukou, Chongshan, Changshashan, 15% or so.

(4) In 1995, by monitored data, no grade-II water appeared in the whole year and the area of waters above grade-III was 76% of the total area. The major pollutants were total phosphorus (TP), total nitrogen (TN) and permanganate index (COD_{Mn}). The apparent symptoms were the aggravation of eutrophication and the drastic proliferation of algae, affecting people's life and production. As regards the water quality of Taihu Lake region, on the whole, that in the eastern and central Taihu Lake was relatively better. The perennial water quality in 1995 was grade-III and the biomass of algae was 3.5-4.5 mg/l. The water quality in Wulihu Lake and Meilianghu Lake was the worst. The perennial water quality was grade-V or worse, the biomass of algae, 15-17 mg/l. For the yearly distribution of eutrophic index in Taihu Lake, the concentrations of TP and TN were the highest in winter and the lowest in summer, while the reproduction of algae was the lowest in winter and the highest in summer.

The water quality of rivers into or out of Taihu Lake was deteriorating day by day. Over a half of the rivers had grade-V or worse water quality (1995), losing usability. The main pollution indices were TP, TN and COD_{Mn}. The TP values of 90% rivers exceeded the grade-III of the water standard. The water quality in rivers into the Lake was worse than that out of the Lake. In flood season, the water quality was better than in no flood season.

The tendency for water pollution variation is the rapid development of eutrophication in Taihu Lake. Its characteristics are that the concentrations of TP, TN and COD_{Mn} increase year after year, the expansion of eutrophic area speeds up, the algae bloom frequently and the duration lengthens, the quantity and biomass of algae dramatically augment, the contents of water pollutants uplift gradually, the water quality of most rivers decreases 1-2 grades, and the polluted sections of rivers increase.

Table 29 Comprehensive assessment and statistics on lake basin, 1992

Lake name	whole area assessed (km^2)	II		III		IV		TP		TN	
		Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Area (km^2)	Ratio (%)	Mean (mg/l)	Trophic level	Mean (mg/l)	Trophic level
Dianshanhu Lake	63.73			33.2	52.1	30.53	47.9	0.103	Eu-	2.217	Eu-
Taihu Lake	2338	1585	67.8	259	11.1	494	21.1	0.064	Meso-eu-	3.14	Eu-
Yangchenghu Lake	119.0			119	100			0.056	Meso-eu-	3.02	Eu-
Gehu Lake	187.0	46.7	25.0			140.3	75.0				
The whole basin	2707.73	1631.7	60.3	411.2	15.2	664.83	24.5				

* Eu- signifies eutrophic level; Meso-eu- signifies meso-eutrophic level.

Table 30 The present situation for the water quality of main waters in Taihu Lake basin, 1992

Rivers and lakes	Length of river courses (km)	Length of assessed river courses (km)(A)	Length of polluted river courses (km)(B)	B/A (%)	Main pollutants
Canal in the south of Yangtze River	312	299.5	248.5	83	Non-ionized ammonia, COD, BOD_5
Huangpujiang River	113	81.3	81.3	100	DO, non-ionized ammonia, volatile phenol, COD_{Mn}
Taipuhe River	57.6	48	25	52	Volatile phenol
Wangyuhe River	60	3	3	100	NH_3-N, DO, COD_{Mn}
Taihu Lake				21% meso-eu-, 78.4% eu-	TN、TP

* Excerpted from data of Taihu Lake bureau. Length of polluted river courses refers to grade-IV or worse than grade-IV water quality. The meaning of "meso-eu-, eu-" is the same to that in Table 29.

To summarize, from the early 1980s up to now, the water quality grade of Taihu Lake degraded one grade. Averagely the whole lake waters are converted from original grade-II waters to the dominant grade-III waters. Most waters of Taihu Lake reached to eutrophic level. Wulihu Lake and Meilianghu Lake had arrived at heavy eutrophic level. Therefore, it is very arduous to make Taihu Lake water quality clean and specially restore to meso-eutrophication by 2010.

The area of Dianshanhu Lake is 63.73 km^2. In 1992, the area of grade-III waters in the whole year was

33.20 km^2, accounting for 52.1% of the total area, and that of grade-IV waters, 30.53 km^2, 47.9%. The perennial mean TP concentration was 0.103 mg/l and the mean TN concentration was 2.217 mg/l. According to the yearly statistics, for TP, 35.1% of waters was meso-eutrophic level, 64.9% of waters, eutrophic level; for TN, the whole lake was in a eutrophic state.

Yangchenghu Lake, 119.0 km^2 of area, meanly belonged to grade-III waters in the whole year. The perennial average TP was 0.056 mg/l, TN, 3.02 mg/l. Counted by a whole year, for TP, 100% of waters were meso-eutrophication, and for TN, 100% of waters were in eutrophication. Synthetically averaged on this lake, for a whole year 100% of waters were in a eutrophic plane. The area of Gehu Lake is 187.0 km^2. Grade-II waters had 46.7 km^2, occupying 25.0%, grade-IV, 140.3 km^2, 75.0%. Perennially 50% of waters were meso-eutrophication.

The total area of the four lakes mentioned above is 2707.73 km^2. The area of grade-II in the whole year was 1631.70 km^2, 60.3% of the total area; the area of grade-III, 411.21 km^2, 15.20% of the total area; grade-IV, 663.83 km^2, 24.5%(Table 29). The data analyzed above are the present situation of water resource in the whole year. In a word, integrating the status in flood season, no flood season and the whole year in 1992, it can be concluded that the water quality in the region was characterized by eutrophication. In 1992, the water was in a state of meso- or eutrophication. Moreover, the concentrations of trophic materials increased slightly compared with that in 1991. The major pollution indexes in Taihu Lake are list in Table 30.

3.3 Frequent Pollution Accidents with Severe Economic Loss

(1) In May, 1988, ammoniated liquid and wastewater containing nitrobenzene leaked from Changxing County fertilizer factory and chemical industry plant of Zhejiang province situated in the southwestern region along the upstream Taihu Lake. They polluted water sources and rendered the waterworks to stop production intermittently half a year. The direct economic loss was 2000 thousand yuan. The daily life of 30 thousand dwellers was affected. In the same month, the phosphoric wastewater exceeding standard from a chemical industry plant in Huzhou City discharged, making scads of fish dead. The economic loss was 2000 thousand yuan.

(2) In July, 1990, it was in high temperature and there was no rain. The water table of Taihu Lake was low. In Meilianghu Lake (Wuxiwan) of northwestern Taihu Lake, the TN was 3.32 mg/l, and TP, 0.08 mg/l because of the affection of wind. The algal aggregation added up to 0.5 m thick. The waters greatly lacked oxygen and became greenish, foul and tacky. There was 44.5 thousand kg of fish dead. The daily production of Meiyuan waterworks was reduced from 200 thousand ton to 50 thousand ton, even without water to supply, thus making 116 factories and plants stop or reduce production. The immediate economic loss was 1.3 hundred million yuan.

(3) In summer, 1994, due to aridness and high temperature, algae prevailed on the 120-km^2 lake surface in the northwestern Taihu Lake. In the vicinity of three mountains of Yuantouzhu, the well-known scenic spot, the algae amounted up to 9 hundred million per liter. The tap water was decaying and with a bad stench. The inhabitants were afraid to bathe with the tap water. Merely in the autumn

fishing season in Suzhou, the yield of silverfish diminished 500 ton (nearly 50%) than that in normal years. The dead fish reached 758 thousand kg, the dead crab, 2,500 kg. The fishery yield reduced 2,390 thousand kg.

(4) Huangpujiang River is the Mother River of Shanghai City. 98% of the tap water for the urban district, approximately 4,500 thousand t/d, is extracted from Huangpujiang River. Most of the tap water is supplied by waterworks in the vicinity of Huangpujiang River. The sewage in the city discharged into Huangpujiang River is pushed up and goes upstream with the influence of tidewater. Therefore, pollution accidents frequently occur for the nearby plants discharge sewage and myriad ships and boats shuttle. The oil pollution made the waterworks around the river often have to reduce the extraction of water for several hours. In 1991, Shanghai coking plant discharged wastewater with derivatives of benzene, making the concentration of phenol in the water sources of Changqiao waterworks along the river rise up to 0.135 mg/l, which transcended 12.5 times of that in grade-IV water standard. Although it was lowered to 0.07 mg/l by waterworks, it still exceeded 37 times of drinking water standard. The bad odor in water incited public violent repugnance. For this, the government of Shanghai City has to invest 26 hundred million yuan to move the water intake up to Songpu Bridge along the river by 27 km. The second-period project has already begun.

(5) The marginal water pollution across administrative boundaries occurred frequently so that disputes were resulted in, which affected the social stability. Shengze Town of Wujiang in Jiangsu province is known as "the first town in Cathay." In May 1994, its wastewater from silk cloth printing and dyeing plant contaminated 5-6 villages and towns in Wangjiangjing in the north Jiaxing, Zhejiang, which almost made the 130 thousand-mu outer lake culture in state-operated Jiaxing City fishery farm completely annihilated. The 10 thousand-mu inner pond culture was also impacted severely. The immediate economic loss was over 500 thousand yuan. The pollution of printing and dyeing wastewater made the drinking water sources for 100 thousand people spoiled. Many people often felt dizzy and had diarrhea and the health of people was harmed. Up to date the water pollution disputes have not been settled properly.

At present, except a few of cities, the majority of drinking water sources for cities in the basin is all polluted and destroyed. The original water intakes have to be moved upstream one after another or shut down to reselect new ones. These cities become water quality-type water-deficient cities. Pollution and water-deficiency do not allow production and life to continue, let alone develop. To protect drinking water not to be polluted is intimately pertinent to the people and society. It also becomes one of the most exigent tasks for the city construction and economy sustainable development.

The economic loss caused by water pollution is quite considerable and the social detriment is extremely immense. According to the investigation, in the economy-developed regions of Suzhou, Wuxi and Changzhou, every year the economic loss caused by water pollution will occupy 5%-7% of the GNP of that year. In 1993, the immediate loss due to environmental pollution in Shanghai was around 62 hundred million yuan, accounting for about 3% of the whole GNP of that year, which greatly exceeded the investment on environmental conservation. The economic loss caused by water pollution rocketed up to 27 hundred million yuan. With the social and economic development, if we don't attach importance to environmental conservation and increase investment, this economic loss will further inflate.It is predicted that to 2000, the loss owing to environmental pollution in Shanghai city will come to 106 hundred million yuan, among which the economic loss caused by water pollution will be 45 hundred million yuan.

Now in Taihu Lake basin due to water pollution, the yearly economic loss is at least more than 50 hundred million yuan. This tremendous number is already a half of the loss, 109 hundred million yuan, caused by extraordinarily serious floods in this region in 1991. This signifies that the economic loss effected by water pollution in every two year is identical to the flood loss in 1991. Furthermore, if we don't harness water pollution, to 2000 the consequential economic loss along the whole watershed would add up to 128 hundred million yuan.

3.4 The Main Causes for Water Quality Deterioration

The following are mainly responsible for the deteriorated quality of water resources in Taihu Lake Basin.

- The great increase in pollutant discharge in the basin, the overloaded drainage of pollutants entering lakes, the inequilibrium of input and output
- The irrational exploitation, the ruin of aquatic purification, transport, transformation, output ability of waters on pollutants
- Very weak construction for wastewater treatment
- The huge deficit of funds for environmental harness
- The effect of tourism
- The perfunctory management on lake basin and not strict law-enforcing

4. Development, Utilization and Protection of Water Resource

Taihu Lake drainage area is an area with dense population and rapid economic development. It is also an area with a water supply shortage measured by per capita demand or by the demand of economic development. Furthermore, worsening of water quality has even caused shortage of quality water in areas such as Shanghai and southern Jiansu Province surrounded by Taihu Lake. Severe unbalance exists between the supply and demand of water in Taihu Lake area.

In order to resolve this problem, it is necessary first to enhance the development, utilization and protection of water resources, increase the availability of water resources; and at the same time, implement strict measures to protect and improve water quality, strictly control the overall volume of wastewater emission to lessen the degree of water quality deterioration and increase the utilization ratio of water.

4.1 Strategies for Development and Utilization of Water Resources

4.1.1 Developing water resources and increasing the availability of water based on local conditions

(1) Developing new water resources, pumping and drawing river water

In addition to improve the utilization ratio of water resources, developing new water resources is necessary to adapt to the increasing demand for water. The main measures are as follows: establish water conveyance facilities, promote and enlarge the water projects along the rivers in south Jiangsu Province as well as the drawing water works of Yangtze River, ensure reasonable management to reduce the shortage of water caused by lack of engineering works in the whole area.

Taihu Lake plain has advantages in its natural geographic conditions with Yangtze River in the north and Qiantangjiang River in the south. The water resource in Yangtze River is rich, and fewer conveyance systems are needed. Normally, 1-1.5 billion m^3 water can be drawn per year from Yangtze River. If Yuhe project is finished, 150 m^3 /s water can be drawn from Yangtze River in high water demand period. The contradiction of demand and supply of water can be mitigated through increasing the quantity of water drawn. But drawing water from Yangtze River in the north have to pass the Great Canal first thus bringing polluted water of some cities along the bank into Taihu Lake, this will impact the quality of Taihu Lake. During extending to get water from rivers, we should maintain the cleanliness of water, consider the conditions and limitations of getting water from rivers and the economic values for dumping and drawing river water and transporting it through a long way.

(2) Developing and utilizing local water resources, protecting the few high quality water resources within the drainage area

There exist a few high quality water resources within Taihu Lake area owing to Tiaoxi water system in the southwest of the area. Tiaoxi water system rises in the north foot of Tianmushan Mountain in Zhejiang Province, the quality of water is good before it flows out of the mouth of the mountain. This is the best quality water within the Taihu Lake area meeting Class II of the national standard GB 3828-88. The precipitation of Tiaoxi drainage area is rich with annual volume of 1450mm, this is about 1.5 times the average figure for the whole Taihu Lake drainage area. The annual average flow rate of the east and west branches of Tuiaoxi water at the mountain mouth is 32.74 m^3/s and 47.24 m^3/s respectively with total runoff of the two branches reaching 2.522 billion m^3. Even in dry years, the backward flow volume could reach 1.4 billion m^3. Once these quality water resources are well protected, as much as 0.4 billion m^3 of good quality water can be used to supply the adjacent cities' increasing demand for water.

(3) Rationalization of the exploitation, usage, and the control of underground water resources

The Water Resource Administration Council should be established to enhance the control of underground water resources, prevent excessive extraction of underground water resources and ensure the appropriate exploitation, usage and protection of underground water resources. The surface water of the whole Taihu Lake area has been seriously polluted causing great problem for potable water quality. In regions where there is plenty of underground water resources, appropriate extraction and usage of this resource will help to ease this problem. Two sets of water supply systems should be established in newly developed areas in a city, i.e., potable water supplied from premium underground resources and usage water from surface resources. Because the surface water is polluted seriously, Shanghai, Wuxi and other cities have to extract the underground water in large volumes bringing series of environmental problems: the low level of the underground water, earth subsidence and so on. The level of underground water in Shanghai has been dropping 5mm annually and reaching 3-4m within 30 years in extreme serious areas. In areas which suffered from excessive extraction, proper measures should be in place to prohibit opening new wells, control the extraction, establish perfect supervision system for earth subsidence and reinject ground water into underground system.

(4) Sufficiently protecting water resources, preventing water pollution and making full use of limited water resource

Taihu Lake is one of the most developed industrial areas in China. It is also the area with the most developed rural enterprises in the country. Consequently the water pollution is rather serious. This leads to shortage of water due to poor water quality, e. g, the quantity of water drawn to Shanghai (most from fresh Yangtze River water) should be enough for the demand of all kinds of industries. But the water is polluted seriously, especially in Huangpujiang River plain along the seacoast, the east area of Taihu Lake and Chengxiyu area. The quality of water within these areas can be rely meet class III. The water pollution in Southen Jiangsu Province part of The Great Canal and the city part of Huangpujiang River are seriously polluted. The river water often becomes dark with unpleasant odor decreasing the availability of water resources greatly. The ground water situation of the city is even worse. Protecting water quality, preventing and controlling water pollution and making full use of limited water resources is the main way to improve the quality of local water and resolve the unbalance between water supply and demand.

4.1.2 Increasing the water storage of river, lake and reservoir, regulating the annual and seasonal changes of water resources

The natural reservoirs and lakes play important roles of storing water resources and regulating runoff, especially the big and middle lakes. The regulatable water storage of the lakes in Taihu Lake plain reach to 6.8 billion m^3 with 72.8% in big and middle lakes. The potential capacity of water storage is great because the water storage will increase 2.3 billion m^3 if the water level of Taihu Lake rises by 1m. There are over 500 small dikes formed by blocking part of lake by about $500km^2$. This has directly decreased the lakes' surfaces for water storage, and the quantity of water which can be regulated is reducing. Blocking lakes should be limited strictly. If conditions allow, the fields made by blocking lakes should be returned to lakes. For deeper lakes with sediment silt, dredging should be done to increase capacity to store water. Main projects should be strengthened, at the same time, remove mud and eliminate obstacles in the river beds, recover and increase the capacity of rivers for water to pass through and be stored. Big and middle lakes especially Taihu Lake should be protected as the important conservation areas of water resources. It is very important not only to regulate water, utilize water but also control it by balancing water volume in low period with that in high period.

4.1.3 Promoting the measures of saving water in agriculture, industry and cities

(1) Adjusting industrial distribution, reducing the quantity of industrial water use

Saving water resources includes adjusting industrial distribution and reducing the quantity of water consumed by industry. When regulating the distribution of industry, the availability of water resources should be considered.

(2) Renewing the technology and equipment of production process, cutting down water consumption ratio per unit production and per ten thousand Yuan output

Advanced technology and modern equipment are the most important factors to cut down water consumption per unit production and per ten thousand Yuan output. The quantity of water consumed by industry average per ten thousand Yuan output ranges from 600t to 300t with difference sometimes of 1.5-2.0 times. In our country, 20-40t and 200-500t of water is needed to produce 1t steel and 1t paper while the figures are 3-5t and 100t in developed countries. To produce ten thousand Yuan industrial output, almost 400t water is needed in China while only 40t or so in developed countries. Therefore equipment with outdated technology and low resource conversion ratio and high water consumption rate should be replaced by modern equipment with advanced technology to increase the resource conversion ratio and lower water consumption rate. It is necessary to strengthen the management of equipment operation, check and repair the facilities regularly to maintain them in good condition, establish the system of careful maintenance of equipment and the system of positional responsibility so to cut down the quantity of water consumption.

(3) Adopting advanced irrigating technology , and saving water of irrigation

The irrigation method generally used in agriculture in our country is by flood irrigation. Most irrigation ditches were built in 1960s. They are aging rapidly and not being repaired timely causing the efficiency declined considerably. At least $750m^3$ water will be needed to produce 1t dry cereal, $5000m^3$ water will be used to irrigate 1 hc wheat. The quantity of water used to produce rice is 3-4 times of the figure for wheat. Based on these facts, advanced irrigating technology must be adopted for sustainable development of economy, i.e., the system of pipe line distribution, the technology jointly using channel with motor-pumped well ; irrigating both in ditches and ridge-bordered plots; the technology of sprinkling irrigation, drip irrigation and micro irrigation, the technology of transmitting water in low pressure pipe and so on. In addition, the water in soil is protected by raking soil softly. Using the technology of controlling water evaporation such as ground films and water dispersant have achieved apparent effects on reasonable utilization for water resources. The output of corn increased by 30% using the ground film covering technique, at the same time, the quantity of water consumed dropped to $480m^3$. The water usage efficiency will rise to 0.72 by jointly using channel with motor-pumped well. The consumption of water can be saved by 30-50% and output will increase by 10-20% with the utilization of sprinkling and micro irrigation technology. In a word, if the water usage efficiency rises by 0.15 by adopting advanced irrigating methods, 2.5-3.5 billion m^3 water can be saved each year. It is also necessary to choose crops consuming less water and reduce plant areas of crops consuming more water. We should consider the facts of available water resources, research and promote dry planting in irrigated fields and anti-drought corns, regulate the structure of agriculture, even develop agriculture irrigated by salt water to reduce the impact on agriculture caused by shortage of fresh water. These are the ways for developing agriculture in areas short of water.

4.1.4 Strengthening the management of water resources and perfecting the legal system

(1) Enhancement of the water resource management

Unifying the management of water resources is the basic principle. But in many areas, there has not been a focused authority and the providing water in cities belongs to three departments: Running Water Company, Self-provision for Drawing River Water Department and Deep Well Water Department. They are managed respectively by The Water Conservancy Bureau and The Energy Saving Office which make different department work separately. This is not helpful to rationalize limited water resources. Therefore it is indispensable to establish unified organizations, enhance the management of water resources in Taihu Lake and in main rivers flowing to big rivers and the lake, control water pollution in all these water bodies. These measures are helpful to satisfy the water demand in economic development in the whole area.

(2) Perfecting the water usage fee charge system in the different sections within the drainage area

Based on the existing measures on water conservancy, the system of charged utilization of water resources should be instituted under the support of both central and local governments. Fees that can be charged include: fees for providing water in water conservancy projects, fees for water resources, fees for technical consulting of water resource and so on. It is important to form such system to manage price of water resources. For a long time, the standard of water fees and its value have been distorted seriously, fees per $1m^3$ water is only a few Cents (Fen), or even less than one Cent and the rate of collection only reached 70%. The water price is too low to make peasants change the old habits of using water. The low fee is not possible to help them realize the importance of saving water in production and daily living. Adjusting the price of water and increasing it properly through the economical leverage can strengthen the consciousness of saving water. It is no doubt that this will play a decisive role for saving water in agriculture.

(3) Making out relevant rules and terms to water resources

Water should be managed and utilized by laws. According to the plan of the drainage area, the management of water resources should also be unified. Developing, using and protecting water resources as well as preventing all kinds of water from being harmed should be regulated by law. It is very important to set up the system of rules within the area. The certified usage of water and the law of promoting the reasonable development and utilization in Taihu Lake area should be formed as soon as possible. The development and utilization of water resource including planning, implementation, regulation, duty, right and liability should be defined into law to promote the further development.

4.2 The Countermeasures of Protecting Water Quality and Environment

The basic reason of water pollution and environment deterioration is that the gross volume of wastewater and pollutants poured into water bodies surpasses its environmental capacities, the self-cleaning ability, and the maximum load capacity. The mitigation, transmission and ways of export of pollutants are stopped and weakened resulted from human interruption or destruction. Therefore, the pollutant input surpasses output, leading to the ecological unbalance and ecological blockage. It is fundamental to solve these basic causes for cleaning water quality, protecting and improving water environment, promoting the ecological balance, the countermeasures are to control the polluted resource and develop new water resources, reduce the total waste water volume and pollutants into water bodies, increase the quantity and ways of its mitigation, transmission and export. Measures mainly are as follows:

(1) controlling resources of pollution, the volume of polluted water and pollutants should be controlled according to the environmental capacities which the water body can hold, the maximum load allowed and self-obstructive abilities;

(2) dredging the flow channels, resolve the bottle-neck problem;

(3) activating the network, regulate the structure and function, dredge the ways for pollutant's migration, transmission and flowing out of water bodies, ensure smooth flow;

(4) reducing mud, dredge the obstructed ecological flow;

(5) enhancing internal power, increase the self-cleaning and self-adjustment abilities of water bodies for the inflow of polluted water and various pollutants.

4.2.1 Defining the overall goal of volume control, water bodies which should be mostly protected and areas which should be mostly protected from pollution

The annual volume emission in Taihu Lake area has reached over 3.5 billion ton per year, 80% of which hasn't gone through any treatment or, even if it has gone through some treatment, it has not reached the standard for emission to rivers and lakes. It is indispensable for us to define the overall goal of volume control, define water bodies which should be mostly protected and areas which should be mostly protected from pollution.

4.2.1.1 Define the target of total volume control

Based on the calculation of <<the Ninth Five Year Plan for Preventing Taihu Lake from Pollution and the Working Group Plan for Year 2010 >>, the quality standard for collectively portable water source and that for rivers flowing into and out of Taihu Lake meet class III standard of ground water. The maximum volumes of emission allowed in Taihu Lake area are as follows: TP 4112t/a; TN 19021t/a and COD_{Cr} 199097 t/a (Table 33).

Table 31 The Characteristics of main pollution controlled areas in Taihu Lake

Name	Scope	Protection objects	Characteristics	Province
Wuli lake - Meiliang lake seriously pollution controlled area	Liangxi river, Zhihu port, Wujin port and upstream, including Danyang city, north of The Great Canal in Changzhou city, South Yangtze River and Wuxi city urban area and part of suburb.	Wuli lake, Meiliang lake and Liangxi river, Zhihu port and Wujin port.	The areas are the most seriously polluted areas around Taihu Lake characterized by small areas and heavy polluted load, greatly influenced by human activities. They are main portable water resources with three rivers connecting with The Great Canal	Jiangsu Province
West of Taihu Lake pollution controlled area	Drainage basins of Caoqiao river and Yili river, including the whole city of Yixing, Suyang and Jintan, south of The Great Canal in Danyang city and Changzhou city	The water area along west and northwest Taihu Lake (including Zhushan lake), & Taige Canal, Caoqiao river, Yilu river, Gehu & so on.	They are the areas with most pollutants emission which distribute widely. The surface pollution is serious too.	Jiangsu Province
West of Zhejiang Province pollution controlled area	Changxing port, the whole drainage basins of west and east Tiaoxi river, the area of Hangzhou, Jiaxing and Huzhou covered by east and south of Taihu Lake areas. Including the whole city of Huzhou and Jiaxing and part of Hangzhou city.	Water areas along southwest and south Taihu Lake, Changxing, port, west and east Tiaoxi.	Tiaoxi drainage basin is the mountain area with forest in Taihu Lake area. There exists serious soil erosion and water loss problem. It is the seriously polluted area in western Zhejiang area.	Zhejiang Province
Wangyu river pollution controlled area	areas 5 km wide from the center line of Gonghu lake and Wangyu river, including Changshu city, Wuxi city and part of Suzhou city.	Gonghu lake and Wangyu river	Wangyu river is the important river source for drawing water from Yangtze River to Taihu Lake with volume of 2.8 billion m^3 in dry years. The drawn water quality has influenced the quality of Taihu Lake directly.	Jiangsu Province
The lakeside pollution controlled area	The area of 5 km around Taihu Lake, including Huzhou city, Wuxi city, Suzhou city and part of Changzhou city	Water bodies along Taihu Lake	Lakeside planning protection area is within 5 km of Taihu Lake. It is the last protection area for pollutants entering into Taihu Lake and has the greatest connection with pollutants flowing into lakes. It is also the area with direct human activities influence.	Jiangsu Province and Zhejiang Province

Table 32 Targets for overall Pollution Volume Control

Controlled area	Index	Present volume of emission (t/a)	Maximum allowed volume of emission	Maximum allowed volume of entering into Taihu Lake	Province
Wuli lake - Meiliang lake seriously polluted control area	COD_{Cr}	48838	21136	8742	Jiangsu Province
	TP	1225	319	91	
	TN	17549	1162	412	
West Taihu Lake lake pollution controlled area	COD_{Cr}	60570	44238	22844	Jiangsu Province
	TP	1478	859	245	
	TN	17528	1537	545	
West of Zhejiang Province pollution controlled area	COD_{Cr}	56784	38614	.16023	Zhejiang Province
	TP	982	336	101	
	TN	14120	1131	401	
Wangyu River pollution controlled area	COD_{Cr}	27623	11049	4585	Jiangsu Province
	TP	671	204	58	
	TN	7661	612	217	
Lakeside pollution controlled area	COD_{Cr}	18298	11894	435	Jiangsu Province and Zhejiang Province
	TP	651	190	54	
	TN	11926	1148	407	
East Taihu Lake - Taipu lake pollution controlled area	COD_{Cr}	11919	5791	2403	Jiangsu Province, Zhejiang Province and Shanghai city
	TP	161	133	38	
	TN	3233	522	185	
Total	COD_{Cr}	224032	132722	59532	
	TP	5168	2041	587	
	TN	72017	6112	2167	

Note: The target of total volume control is allocated to the emission management authorities of subordinate district by every province in stages.

Table 33 Maximum allowed volume of emission and the volume into Taihu Lake in 2000

Control index	Maximum volume allowed into Taihu Lake	*Maximum volume of emission
TP(t/a)	1439	4112
TN(t/a)	9138	19021
CODcr(t/a)	96759	199097

Note: The maximum volume of emission allowed in 2000 includs precipitation, dust sedimentation (resource unable to control: TP: 93t/a; TN: 3181t/a; COD_{Cr}: 23595t/a)

Table 34 Maximum volume of emission allowed by each province in 2000

Control index	Jiangsu Province	Zhejiang Province	Total
TP(t/a)	3255	764	4019
TN(t/a)	12671	3169	15840
COD_{Cr} (t/a)	121866	53636	175502

The target of overall volume control in 2010 is to maintain middle nutrition standard for Taihu Lake. Maximum volumes of emission allowed in Taihu Lake area are as follows: TP - 2285t/a; TN - 9635t/a; COD_{Cr} - 185234t/a (Table 35). The maximum volumes of emission allowed by Zhejiang and Jiangsu Provinces are listed in Table 36.

Budgetary estimate for investment: According to preliminary estimate, 20.42 billion Yuan will be needed to maintain middle nutrition for Taihu Lake in 2010. The division of the capital needed will be: Jiangsu province 11.23 billion Yuan, Zhejiang province 8.43 billion Yuan and Shanghai city 0.76 billion Yuan. 510 prioritized projects are arranged in the program, others need to be arranged integrally by every province.

Table 35 Maximum allowed volume of emission and volume into Taihu Lake

Control index	Maximum volume into Taihu Lake	Maximum volume of emission
TP(t/a)	719	2285
TN(t/a)	5483	9635
COD_{Cr} (t/a)	90761	185234

Note: The maximum volume of emission allowed in 2010 includes precipitation, dust (source unable to control): TP - 93t/a; TN - 3181t/a; COD_{Cr} - 23595t/a.

Table 36 Maximum volume of emission allowed by each province in 2010

Control index	Jiangsu Province	Zhejiang Province	Total
TP(t/a)	1774	418	2192
TN(t/a)	5163	1291	6454
COD_{Cr}(t/a)	112239	49400	161639

4.2.1.2 Dividing the mostly protected water bodies and areas which should mostly be protected from pollution

To control the pollution and the nutritionlization of Taihu Lake, it is most important to stress the priority, define the water bodies which should be mostly protected and areas which should be protected from pollution. The following areas should be protected :

- Meiliang Lake (including Wuli Lake): 135km^2
- Gonghu Lake: 147km^2
- East Taihu Lake: 158km^2
- Water body near Xukou area: 150km^2

Considering the pollution load distribution and the regional targets for water quality protection, the following six areas should be protected from pollutants:

- Meiliang Lake---Wuli Lake serious pollution controlled area;

- West Taihu Lake pollution controlled area
- West Zhejiang province
- Wangyu River pollution controlled area:
- Lakeside pollution controlled area
- East Taihu Lake---Taipu River pollution controlled area

These six pollution controlled areas occupies more than 80% of the whole Taihu Lake area. The TP from the six pollution controlled areas reaches 5168t/a which represents 91% of the total volume in Taihu Lake area; the figures for TN are 72017t/a and 91% and for COD_{Cr}, 224032 t/a and 79% respectively.

4.2.2 Controlling pollution sources and reducing the total amount of wastewater and pollutants discharged into natural waterbodies

4.2.2.1 targets of pollution source controls

By the end of 2000, the wastewater from industrial pollution sources, intensive breeding plants and hotels & restaurants bordering on Taihu Lake basin is required to comply with "the standard of wastewater comprehensive discharge"(GB8978-96). The industrial standards should be obeyed firstly if they exist. The polluters whose wastewater contains N and P should be required to comply with the standards including N and P. The areas that have the local standard of wastewater discharge should carry out the related items in the local standard except the items looser than that of the national standard. The new wastewater treatment facilities are demanded to introduce the procedure of de-nitrogen and de-phosphate. The wastewater discharges:

- The wastewater discharged into the main streams, the first-class branches and the sources of drinking water should comply with the standard of grade I, and the wastewater that discharged directly into Taihu Lake should meet the local standard that is stricter than the standard mentioned above.
- The wastewater discharged into the areas of IV and V should obey the standard of grade II;
- The wastewater discharged into the urban sewage systems leading to secondary sewage treatment plant should comply with the standard of grade III.

4.2.2.2 treatment of the industrial pollution sources compliance with the standards

(1) Adjustment of the industrial structures

The reduction of wastewater and pollutants discharge should be with a view to the optimization of the industrial and product structures, the rationalization of the enterprise's production scale, and strengthening the interior management system of enterprises. The enterprises should pay more attention to tap the interior potentials of production, to decrease the cost of product manufacturing, to increase the quality of products and to reduce pollution. It is not comme il faut for enterprise to seek solely for economic benefits, particularly on the basis of expanse of environmental pollution, ecological resources destruction and loss of ecological service function. The projects causing heavy pollution are never allowed to build, and the pollution enterprises built previously that can't be improved should be closed up, stopped, combined, transferred and relocated. According to the targets of the plan, the industrial enterprises within the Taihu Lake pollution control area should be improved comprehensively and thoroughly. The "fifteen small "enterprises that pollute heavily and have no hope to improve, such as paper mill with the production capability of less 5000 tons annually, should be closed up, stopped without hesitance. The pollution enterprises that don't comply with the standard are required to be controlled within a specific time. Totally 104 enterprises causing pollution have been closed up, stopped, combined, transferred, and relocated by the end of 1998, in which 54 enterprises are in Jiangsu, and other 50 enterprises in Zhejiang. The projects that are required to control within a specific time were totally 203 at the end of 1998, and the total investment is 550.45 million RMB, including 110 projects in Jiangsu with the total investment of 2888.38 million RMB, 89 projects in Zhejiang with the total investment of 259.93 million RMB, and 4 projects in Shanghai with the total investment of 2.14 million RMB.

(2) Introducing the new equipment and technologies, improving interior management of enterprises

Advanced production procedures and equipment could reduce greatly the raw material loss and harmful & poisonous materials that doesn't decompose easily directly entering into the environment. It is necessary to review the behaviors of some enterprises and to abandon gradually the conventional production procedures and technologies that have low rate of resources transformation, and pollute heavily. Meanwhile, the modern enterprises should introduce the advanced production procedures and equipment that have high rate of resources transformation, low material and energy consumption, and a little amount of pollution emission. It is required to strength the management of equipment operation, to check and maintain the equipment periodically, to build guarantee system of equipment operation well and system of post responsibility, and to introduce clean technology. A whole process management, from raw materials, product manufacturing, packaging, transportation to consumption, is necessary. The purpose is to make the best use of resources, to manufacture produce with the lowest amount of materials and energy, to minimize the solid waste and wastewater discharge and to turn the wastes into resources (the recycling, reuse, transformation of waste and wastewater).

(3) The use of raw materials and supplementary materials

The industrial enterprises should adopt the techniques of source reduction, and alter the procedures of product manufacturing, equipment operation and the use of raw materials. It is very useful to reduce the risks of public health, safety and welfare and environmental destruction by using the low poisonous and harmless materials. Much attention should be paid to raw materials use in new project designs. For some old projects, it is better to alter the use of raw materials by technical reform.

(4) Strengthening the raw materials recycling

Building a looped production system within the enterprises could raise the rate of the resources use and transformation. It is a good way to recycle the resources, to raise the rate of resources use and to reduce the discharge of waste and wastewater, such as the reuse of cooling water, the recycling of whitewater and alkali in paper manufacturing industry. This can be called the interior recycling of materials. The resources that can't be used within the enterprises can develop exterior looped production system by the combination with other industries. The organic wastewater in some food industries can be used to produce biogas, yeast and feedstuff, etc., which also decrease the environmental pollution. This is usually called exterior recycling system of materials.

4.2.2.3 treatment and utilization of urban sewage

Recently, there are total 33 wastewater treatment plants (WWTP) that are going to build in Taihu Lake basin. The total capacity treating wastewater is 1,641,600 m3/d, including 1,005,600 m3/d of newly built and 635,000 m3/d of expanded WWTP. The intending investment is 3341.62 million RMB in total. The WWTP includes 28 ones with the total investment of 1971.5 million RMB and the treatment capability of 635000 m^3/d in Jiangsu, and 5 ones in Zhejiang with the total investment of 1370.12 million RMB and the treatment capability of 1 million m^3/d.

Meanwhile, the WWTP that is on the spot, decentralized, small scale, no power and underground should be adopted. The construction and maintenance of WWTP usually needs much money, and some cities usually can't afford the high operation expenses, even if the WWTP had been built. It is difficulty for China as a developing country to solve the issue of urban sewage solely depending on building of some centralized WWTP. The wastewater treatment engineering that is on the spot, decentralized, small scale, no power and underground has the advantages of little land occupation, low investment and operation expenses, such as the wastewater treatment equipment newly built or septic tank reconstructed near the building or within living area.

The fecal sewage is detached from the washing water at the source of wastewater. The fecal sewage goes through the pretreatment tank with grille, and the solid waste that can't be decomposed easily, such as rubber and plastic is removed and the left enters into the anaerobic ferment system for the production of biogas. Counting as 1.5kg of feces excreted by one person a day, and 0.15m^3 of the anaerobic ferment tank occupied by one person, a biogas tank of 15m^3 can be used by 100 persons and the fecal sewage can keep 7-10 days in the tank. The tanks, usually 2-4 in the living areas can be connected in series, and the wastewater treated in the former tanks can be discharged into the first sink of subsequent tank. So it can increase greatly the biogas production and the effect of biogas clean, and can reduce the investment of pipeline system. The content of COD and BOD_5 of fecal sewage can be reduced respectively from 280mg/l, 150mg/l at the entrance to 80mg/l, 30mg/l after being treated. The wastewater treated is compliance with the class I of *national standard of wastewater comprehensive* *discharge*, even class II sometimes. The treated wastewater can be recycled to fish in yard or to irrigate the forest or discharge into the natural water. The ferment of 1 m^3 wastewater can produce 0.2-0.4 m^3 biogases, and one tank can produce 3-6 m^3 biogases per day. The biogas, after being desulfurated can be used for cooking. The cost of building a biogas tank is about 9000RMB and is 800-1000RMB more than that of building a new septic tank. The biogas tank doesn't need power and therefore hasn't input of operation expenses. Counting as 1000 m^3 of fecal sewage treated per tank annually, the clean capability of such 1000 wastewater treatment pond in a city with 100 thousand people is equivalent to that of a centralized WWTP with the treatment capability of 1 million m^3. The investment of the former is just 1/5-1/10 of that of the latter. The wastewater treatment pond not only can save more than 1 million kwh electricity and 2 millions RMB operation expenses annually, but can reduce the land occupation and management cost, and can recycle a part of biogas and its residues for agricultural use.

The domestic sewage, such as washing wastewater mixed with grit, greasy dirt and a little amount of detergent can be recycled after being treated slightly. The recycling of domestic sewage is an effective way to save water resources and reduce the wastewater discharge in the area of lack of water resources. The equipment can be used to remove the grit and greasy dirt in the wastewater before recycling. The grit is usually removed in the depositing tank, and the equipment installed at the exit of precipitating tank eliminates greasy dirt. The equipment includes the floating oil collection slot, track oil remover of DO-600 et al. The greasy dirt flows into underground oil collection buckets and can be recycled, and the wastewater treated can be used for washing floor, car and lavatory and also for yard irrigation. The wastewater of 77 hotels within the 5 km area of Taihu Lake region has been compliance with the standard by the end of the 1998. The procedures of de-nitrogen and de-phosphorization is required to adopt in domestic sewage treatment, and the total investment is 150 million RMB.

4.2.2.4 Surface pollution sources control in farmland

The annual amount of fertilizer uses in the watersheds is averagely 2-3 million tons, 100-200 kg per mu. Pesticides are 50-80 thousand tons or 2.8 kg per mu. According to spot check, half of the fertilizer used in farmland, about 40-60%, is lost into water that becomes an important surface pollution source. Therefore it is very critical to control this kind of contamination. Its methods mainly include scientific fertilization, reduction of the amount of fertilizer uses along with maintaining the original or increasing crops yields; producing and popularizing ecological fertilizer to reduce its loss rate to lesson the concentration of nitrogen and phosphorus in circumfluent water through farmlands. Fertilizer, although holding 45% of nutrition elements such as nitrogen, phosphorus, potassium, be subject to losses. This makes not only a big waste, raises the economic cost and input in agriculture, but also leads to nutrition abundant for surface water pollution. And long-period utilization of fertilizer also results in bad conditions of soil structure, for example, soil hardness, bad features for breath and infiltration freely with little manure be used. It is one of our traditional manners to ferment organic substances, excrement and green fertilizer, for example, to make compost which has been not easily accepted by farmer in recent years. The main reasons of it are its lower nutrition contain about 3-6%, lower and slower effect of using, bigger amount of usage, more labor needing, although it has longer effective period and is good for soil improvement. In addition, compost, a non-industrialized and very dirty process is difficult to keep, can not insure the supply, especially unconformable to the requirement of agricultural modernization. Ecological complex fertilizer can be made by the reasonable combination of animal release, green fertilizer, organic wastes, fertilizer and trace elements. Ecological fertilizer, compacting organic matter in organism and inorganic matters in fertilizer, can not make the nutrition in it kept easily, can heighten nutrition use rate, and overcome the shortcomings of the both. It also make good combination between land use and breeding, long and short term effects, industrialized production and commodity supplying. Total investment of an annual 10 thousand ton factory of ecological complex fertilizer with animal manure as raw materials is about 3-4 million yuan RMB, total cost is about 8 million yuan RMB, and production value is about 11-12 million yuan RMB, annual net efficiency is about 3-4 million yuan RMB that is very marked. In addition, The usage of ecological fertilizer can reduce about 50-60% nutrition loss than single fertilizer. And it may also boost nutrition use rate, reduce fertilizer use amount, save economic cost and input, but also decrease surface water pollution. Utilization and sale of detergents containing phosphorus will be banned in first and secondary protection areas in Taihu Lake from Jan. 1, 1999. In third protection areas, it should be kept in a certain amount.

4.2.2.5 Surface pollution control of the lake

Integrated netted fishery in taking water places in drinking water source (Wuli lake, Meiliang lake, Gong lake, East Taihu Lake and near Xukou areas) should be replaced by the end of 1998. Mechanized fishing is also prohibited. The area of fish breeding in the lake must be controlled in 15 thousand mu. Mechanized fishing ships should be reduced step by step from now 400 to 200 in the end of 1998.

Engine-generated ships should be banned in the special protection watersheds (Wuli lake, Meiliang lake, Gong lake, East Taihu Lake and near Xukou areas). Changing tourism ships into electricity-driven ones. Collection devices of sewage and solid wastes should be installed in ships for concentrating treatment ashore. Devices of sewage and waste treatment and conveyance should be installed. Tourism infrastructure construction should be controlled strictly so as not to increase new pollution source.

4.2.2.6 Building a series of pollution control pilot engineerings

According to the plan, a series of pollution control pilot engineerings should be set up to realize the purpose of ecological restoration of Taihu Lake and offer technical preparation for next-step activities. 8 pilot engineerings, such as agricultural surface pollution source control, ecological agriculture, bottom mud dredged up engineerings etc. are included (Table 37) with total investment of 54 million yuan RMB.

Table 37 Projects details on pollution control pilot engineerings

Items	Investments 10^4 yuan RMB	Remarks
Little waste farm control engineering	400	First protection area of the west parts along with Taihu Lake
Preposition reservior engineering	450	First protection area of the west parts along with Taihu Lake
Big aquatic vegetation restoration engineering	700	Shallow water area of the northeast parts along with Taihu Lake
Algae collection and integrated utilization engineering	300	Meiliang lake area
Ecological agriculture engineering	500	Zhejiang province
Protection belt engineering in bank	750	First protection area of the west parts along with Taihu Lake
Bottom mud dredged up engineering	300	Dredging up 100 thousand m^3 of bottom mud
Cleaning production engineering	2000	Zhejiang and Jiangsu provinces

Table 38 Statistics on investment of pollution source treatments in 1998

Investments (100 million RMB yuan)	Industrial pollution treatment	Foul water treatment	disposal of hotels and restaurants wastewater	pilot engineerings	Total
Jiangsu province	2.8838	19.7150	1.5	0.34	24.4388
Zhejiang province	2.5993	13.7012		0.20	16.5005
Shanghai	0.0214	/		/	0.0214
Total	5.5045	33.4162	1.5	0.54	40.9607

Note: Industrial pollution treatment investments belong to important pollution source treatment cost, excluding costs of "shut down, stopping, combining, transforming and moving away" in this factories.

Total estimated investment of pollution source control is estimated about 4.09607 billion yuan RMB in which 550.45 million RMB is for the disposal of industrial pollution, 3.3 billion RMB is for foul water, 150 million RMB is for the disposal of hotels and restaurants wastewater along the lake, 54 million RMB is for the pilot engineerings. The investments of the three governments are 2.4 billion RMB from Jiangsu province, 1.6 billion RMB from Zhejiang province, 2.1 million RMB in Shanghai city.

4.2.3 Adjusting structure and function of some water ecosystems, rehabilitating disturbed or destroyed ecosystems, and improving their self-cleaning and self-modulation functions

Based on ecological engineering principles of holism, harmony, self-generation and recycling, the adjustment of structure and function of systems is carried out with methods such as increasing rings of material cycling in chains and webs, linking parallel systems without mutual connections, using products, by-products and wastes through different layers and grades, promoting the sound cycling of materials, restoring the structure of destroyed ecosystems, etc. The purposes of it are to improve systems'self-cleaning and self-modulation function, and increase the production of valuable products simultaneously. This means the integration of production with environment, and that of treatment with utilization. For example, through getting back and proliferation of aquatic vascular plants, the flow channels through organic matter to nutrition salinity to water weeds to forage, fertilizer or as some industrial raw materials to transferrence, transformation and output out of waterbody is dredged and enlarged in some systems that water weeds have been weakened or destroyed. In addition, through setting free or netted breeding some kinds of fishes that eat phytoplankton in preconditions of not throwing down any bait, such as silver carp, bighead carp and chub, the flow channel of transferrence, transformation and output from waterbodies through organic matter to the salinity to algae to fish is dredged and enlarged. The purposes of this process are to change harmness into advantages, waste into treasure. This not only increase the approaches and amount of transferrence, transformation and output from waterbody of some salinity and organic matter, but also improve its self-cleaning and self-modulation function, reduce treatment and transportation cost of these wastes, increase economic and social efficiencies.

4.2.4 Strengthen regulation construction for water pollution treatment in Taihu Lake region, make management and rules performance of pollution control more effective

The major measures can be listed as follows:

- Strengthen regulation construction for water pollution treatment in Taihu Lake region
- The verification of total amount of wastewater discharged should be put into effect all over the region
- Governments in different levels in the three provinces and cities should carry out industrial

structure adjustment, and implement clean production strategies

- All of the projects that are newly built, or rebuilt, or scale-expanded must implement the institutions of environmental influence evaluation and the system of "three approaches contemporary implementation"
- The construction of sewage treatment factories and water factories should be put at the same time
- Reinforce disposal of foul water from village and town in Taihu Lake areas
- Giving a strongly environment publicity and sound management planning
- Offering strict overlook and check, and carrying out severe punishment to the irregularities

4.2.5 Looking for increasing environmental investment from every sources by different channels

Pollution governing projects in Taihu Lake region should be done along with the infrastructure and technical reform of locals and the state. These projects should be broken into different parts and be arranged to related areas and enterprises.

Table 39 Classification investment on priority items of water pollution protection in Taihu Lake (100 million RMB yuan)

Engineering sorts	Jiangsu Province	Zhejiang Province	Shanghai city	Total	Rate(%)
Foul water disposal engineering(including hotels and restaurants)	52.50	27.84	0.2	80.54	39.45
Industrial source disposal engineering	2.88	2.59	0.021	5.50	2.69
Surface source disposal engineering	5.44	3.16	-	8.60	4.21
Inner source disposal engineering	7.04	-	-	7.04	3.45
Water conservancy adjustment and drinking water insurance engineering	15.2	14.19	7.38	36.77	18.0
Pollution interception and river channel disposal engineering	12.13	24.06	-	36.19	17.72
Clean production projects	16.75	12.25	-	29.0	14.20
Pilot engineering	0.34	0.20	-	0.54	0.26
Total	112.29	84.30	7.60	204.18	100
Rate (%)	54.99	41.28	3.72	100	

This action should be done in a procedure of applying, assessment, examination and approval by projects owners, and put into practice through different stages. According to the estimate, total investment of priority projects on water pollution protection is 20.4 billion yuan, more details on provincial and different types are as follows (Table 39).

Investment policies and approaches for environment disposal: Principles on investment of Taihu Lake disposal engineering should include explicit aims, planning as a whole, projects fulfilling, implementing in different steps and local investment as major means.

- Increasing environmental investment, giving strong conscience to the principal parts rules of local governments and enterprises in the process of pollution treatment. Creating advantageous conditions for the restoration of watershed ecological environment through raising the percentage of environmental protection investment over national gross in the same time.
- Sewage disposal factories should be taken in the first consideration in city infrastructure. Concrete levying ways for sewage disposal, in addition, must be made as soon as possible to insure normal running of sewage integrated disposal devices.
- Departments of planning and financing of every administration district in the region should give preferential policies to environmental protection investment, in order to support the environmental pollution treatment projects (not including projects of "three approaches contemporary implementation"), and technical renovation projects whose purpose is to avoid pollution. Local administrations and departments in charge may introduce interest subsidies to the projects, especially the great ones that are limited to certain term to encourage enterprises to deal with pollution actively. Drinking water sources should be given priority assurance, and the percentage of sewage disposal and clean production projects should be increased.
- The related policies on environmental protection of the state should be carried out rigorously. Charge collection for all emission enterprises should depend on their total discharge amount of pollutants and should be practiced step by step. The environmental subsidy should be used at some payment. The emission units of pollutants should pay sewage disposal fees.
- Stringent control should be made to agricultural contamination. Ecological agriculture should be popularized in a large effort. Superfluous utilization of fertilizer should be limited through economic ways. The use of organic fertilizer should be encouraged. The chemical products including nitrogen and phosphorus that have great contributions to eutrophication of lakes should be sold in a limited amount in the region. The price of excessively used fertilizer should be higher than other areas in order to decrease the total amount of its usage in the region. The governments of three provinces and cities should launch concrete methods about these activities.
- Discharge of nitrogen and phosphorus for foul water should be reduced with effective means. Utilization and sale of detergents containing phosphorus will be banned in first and secondary-class protection areas in Taihu Lake from Jan. 1, 1999. In third protection areas it should be

kept in a certain amount.

- State's departments of transportation, tourism, agriculture, and environment should assist the three provinces and cities to make related regulations. The pollution discharge management from navigation, tourism and animal feeding in inner rivers should be enhanced. Some devices for wastes collection and transaction of abandoned ships in Taihu Lake region should be set up. An emergency dealing system about pollution accidents must be built step by step to offer a rigid management to dynamical pollution source in this region.

4.2.6 Keep doing researches on Taihu Lake conservation and make the scientific results more popular

To realize the purpose of water quality cleaning, it is necessary to reduce pollution load largely and construct great amount of sewage disposal devices. But it needs combination of various technologies to recover water quality in this kind of very big lake like Taihu Lake. The scientific results on restoration of water quality and eutrophication of lakes gained in the periods of "The sixth –five years plan", "The seventh-five years plan", "The eighth- five years plan" should first be given summary and sieving. The important or suspect issues faced in the process of pollution prevention and cure in this region should be put into scientific planning of related local and state departments after argumentation sufficiently. The projects need be tackled as key scientific problems present mainly include:

- Agricultural surface source pollution engineering technology in river networks areas,
- Large scope of aquatic vegetation restoration researches and scenario print design
- Study on bottom mud dredging up schedule and secondary pollution prevention
- Technology for water pollution emergency disposal engineering in important lake areas
- Study on water and land incorporate management technology. This includes monitoring network technologies, warning system for important protection regions, and the decision-making model on integrated management of Taihu Lake region, building dynamic monitoring and controlling system on the environmental change in Taihu Lake region.
- Gross amount control technologies of pollutants under surveillance and auditing
- Practical technologies suitable for reforming of town enterprises and meeting pretreatment request
- Study on optimal dispatching plan of water conservancy engineering
- Study on the mechanism of "water bloom" in Taihu Lake and its control ways
- Study on the feasibility of sewage interception in Wuli lake and Meiliang lake and water changing engineering
- Study on the feasibility of integrated treatment of Taihu Lake
- Study on soil and water maintenance planning in mountain area in the western part of the lake

and its implementation schedule

- Study on pollution control engineering technology of animal breeding
- Study on the feasibility of waterway through Wu lake-Tai canal and its environmental impacts.

Reference

Cai Qiming, Multianalysis of Dynamic Change and Influence Factors for the Water Quality of Taihu Lake, Science of Lake, 1995, Vol.2, No.7, 97-100

Han Changlai, Mao Rei, Feature of Water System Structure and Change of Function for Taihu Lake Basin, Science of Lake, 1995, Vol.4, No.9, 300-306

Nanjing Institute of Geography & Limnology, Chinese Academy of Science, Research of Water and Soil Resource in Taihu Lake Basin and Perspective for Agricultural Development, Science Press, Beijing, 1988

Qin Beiying, Chen Hesheng, Primary Outline of the Plan of Water Pollution Prevention in Taihu Lake and the Main Rivers Entering it, Water Resource Protection, 1996, No.4, 4-7

She Ziqiang, Water and Soil Resource in Yangtze River Delta and the Region Development, University of Science and Technology of China Press, Hefei, 1997,pp 1-207

Shi Ming, Liu Honggang, Impact to Water Quality of Dianshanhu Lake Caused by Netv Cage Fishery, Rural Eco-Environment, 1989, Vol.3 No.19,7-11

Song Yongchang, Wang Yu, Qi Renhai, Research of Dianshanhu Lake Eutrophication and Treatment, East China Normal University Press, Shanghai, 1992, pp 1-192

Sun Gongdou, Reinforcing Water Resource Management and Relaxing the Conflict between Water Supply and Demand, Water Resource Protection, 1995, No.3, 39-42

Sun Shuncai, Huang Yiping, Yan Jingsong, Taihu Lake, Ocean Press, Beijing, 1993, pp1-271

Sun Zhifang, Mao Rei, Water Resource Usage in Yangtze River Delta, Academic Journal of River and Ocean University (Special for Ocean and Lake),1994, 76-82

Wang Hongdao, Dou Hongsheng, Yan Jingshong, Shu Jinhua, Zhang Yushu Resource of Lake in China—Report of Investigation and Research for the Natural Resource of China, Science Press, Beijing, 1989, pp 1-254

Wang Tongsgeng, Flood Disaster and Profit of Water Conservancy in Taihu Lake Basin in 1993, Science of Lake, 1994,vol.3, No.6, 193-199

Wang Yaobin, Cheng Xin Knolling the Alarm Bell of the Water Problem in Taihu Lake once again, Water Resource Protection, 1996, No.4, 1-3

Yan J.S. & Y.S.Zhang, 1997, Main problems facing endangered Chinese lakes with some suggested principles for their restoration and some examples. In Jorgensen, S. E. &. S. Matsui, Eds. Guidelins of Lakes Management Vol. 8.—The world's lakes in Crisis. International Lake Environment Committee Foundatioin,United Nations Environment Programme. Shiga, Japan, pp. 39-66.

Yan Jingsong, Feature of Eco-engineering of Environmental Protection and Technology, Water Resource Protection, 1994, No.1, 1-7

Towards Sustainable Water Resource Management:

A Case Study in Tianjin, China[1]

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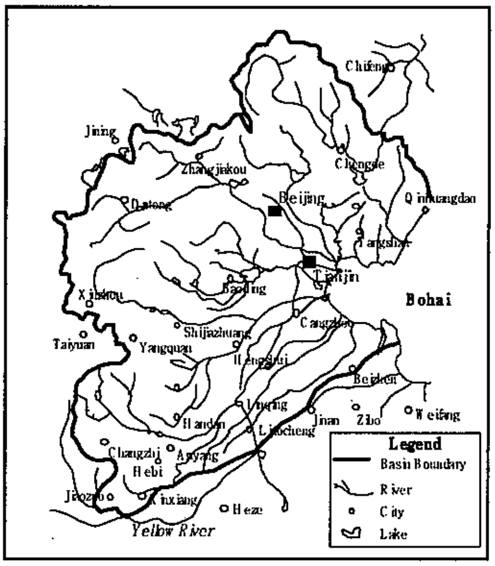
1. Introduction

Tianjin City is located on the Huabei Plain, within the Haihe River Basin in northern China, neighboring the country's capital city of Beijing. Geographically, the city belongs to the warm temperate zone, with annual mean temperatures between 11 to 12 degrees Celsius, and annual mean precipitation of about 560 to 690 mm. One of the country's seven largest river basins, Haihe River Basin is also one of the most polluted and water-scarce. It covers a total area of about 310,000 square kilometers includes portions of five different provinces and two mega-cities. Tianjin City is located at the lowest point downstream of the river (Fig. 1) and covers 11,200 square kilometers, equal to 5.3 times the area of the Tokyo metropolis in Japan. This unusually large scale is an important factor in the following discussion.

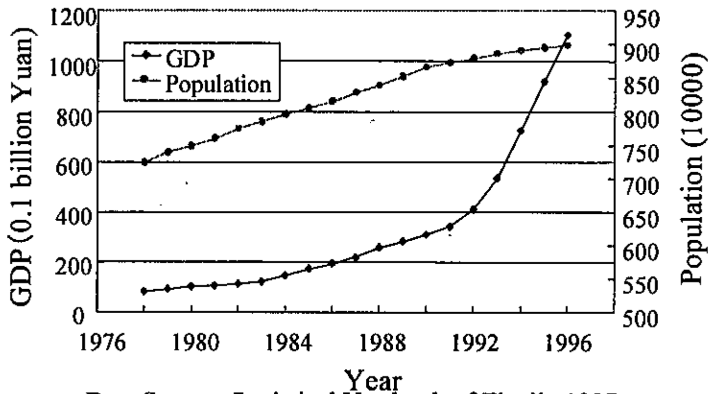
Fig. 1 Water System and Major Cities in Haihe River Basin



[1] This paper will be published in *Sustainable Development* 9, 2001.

Two factors form the background of Tianjin's water issues. One is the imbalance between natural resource distribution and the region's social and economic stature in China. The share of area, population and arable land of the region in the country are 3.3%, 9.8% and 10.9%, respectively, while the share of water resource distribution is only 1.5%. As a result, the per capita water resource is only 430 cubic meters per year, 16% of the country's average level. Despite this, the region plays a very important socio-economic role. The basin holds one of China's five largest urban agglomerations, with Beijing and Tianjin, and Tianjin is the largest industrial center in northern China. The second factor is the rapid industrialization and economic growth of the city and surrounding region have occurred in recent decades. Because water demand upstream has grown rapidly, the downstream city of Tianjin has suffered. Water demand in Tianjin City is also growing. As the GDP of the city grew tenfold from 1978 to 1996, the urban population grew by 1.5 million persons (Fig 2).

Fig. 2 Population and Economic Growth in Tianjin



Data Source: Statistical Yearbook of Tianjin 1997

Among many other concerns, a deficit of total available water resources, overuse of groundwater and deteriorating water quality are three major water resource related issues. The environmental impacts are significant and diverse, including desertification, land subsidence, dropping water tables, saltwater incursion into groundwater, and soil salinization among many others.

This paper examines water resource issues in Tianjin following each step of water resource use in cities, and draws lessons from Tianjin's case through review and evaluation of the measures taken by the municipal government. Based on these, a framework for sustainable urban water resource management is presented, emphasizing the importance of taking full consideration of resource/environmental capacity and an integrated systems approach for problem solving. Together with the framework, the importance of institutional arrangements to ensure the implementation of these strategies is emphasized.

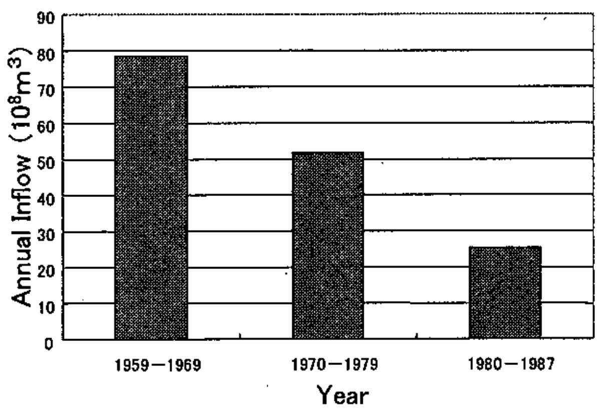
2. A Case Study in Tianjin

Water flow in cities can be divided into four steps. Step 1 is the capture of water from nature as resource. Water resources include water captured within the basin, input from other basins through inter-basin transfers, and newly developed resources like rainwater use and desalinization of seawater. Step 2 is allocation of obtained water resources among regions and sectors. Usually it is distributed between urban and rural areas, and the water assigned to cities is further allocated to different sectors such as agriculture, industry, municipalities and ecological uses. Ecological uses here signify the minimum amount of water necessary to maintain ecosystems and hydrological cycles. Despite the importance of ecological uses, a quantitative understanding of water for these uses is still inadequate. Step 3 is water use within each sector. The efficiency of resource use, recycling ratio, and treatment ratio, etc., will determine the amount and quality of discharge. These factors greatly affect Step 4 which is output and environmental impact. All three kinds of major outputs from urban water use, namely, municipal wastewater, industrial wastewater and agricultural discharge, enter the natural water cycle again, cause various environmental impacts. This four-step water flow can be considered as common to all cities. The discussion of major water resource-related issues in Tianjin will therefore follow each of these steps.

2.1 Input: Distribution of the Water Resource and its Changes over Time

The total water resource in Tianjin of 3.562 billion cubic meters in an average year, includes 2.86 billion cubic meters of surface water and 702 million cubic meters of restorable groundwater. The total can drop to less than 2000 cubic meters in a relatively dry year, and can be further reduced to around 1200 cubic meters in a severe drought. The amount of water resources available to Tianjin, especially surface water, is on a long-term decreasing trend, thought to be a consequence of increased water demand and associated water withdrawal upstream. Fig. 3 shows long term trends in the total volume of surface water entering Hebei Province through rivers.

Fig. 3 Decreasing River Water Inflow to Hebei Province



Data Source: Zhang, D. (1989)

The volume during the 1970s had dropped by one-third of the amount during the 1960s, and dropped another one-third in the 1980s. Since Tianjin is within Hebei Province, it is not difficult to imagine the reduction trend in surface water inflow to Tianjin.

As the local resource deficit became significant, efforts were made to explore new water resources. In 1981 the city started a project to transfer water from Luanhe River, which supplies 1 billion cubic meters of additional water to the city in a relatively dry year. The project was completed and started to function in 1983. Other efforts include sewage water treatment and reuse, and use of seawater for cooling in industry. Treated sewage water is intended to be used for agriculture, with up to 70% being used for irrigation. Due to insufficient operating funding of sewage treatment plants, they cannot operate to capacity, resulting in a large portion of untreated urban sewage being used for irrigation. Seawater used by the power industry for cooling, saves an equivalent of 36 million cubic meters of fresh water each year.

2.2 Resource Allocation

Located at the river mouth, and acquiring most of its surface water through river inflow, water resources in Tianjin City largely depend on how much of a share it gets compared to other areas in the watershed. This section discusses regional distribution issues among three closely related regions: Beijing, Hebei Province and Tianjin. Fig. 4 shows priorities and issues of resource allocation among them.

Fig. 4 Priorities and Issues of Inter-Regional Resource Allocation

Priorities		
I	Beijing	Political predominance Geographical advantage Controls 85% of Haihe river flow
II	Tianjin	Receives sewage in canal from Beijing Most surface water inflow is very low quality Water supply from Miyun/Guanting Dam stopped Receive one billion tonnes of water from Hebei Province through Luanhe
III	Hebei Province	More than half total outflow from mountains of Hebei Province goes to Beijing and Tianjin Dams constructed for agriculture now supply Beijing and Tianjin Effluent from cities are used for agriculture Strong constraints on economic development

Beijing, the capital of China, is located upstream of Tianjin. It is superior to Tianjin both politically and geographically. With the rapid growth of its water demand, Beijing constructed many dams and reservoirs upstream, and now controls up to 85% of the total flow of the Haihe River. From the viewpoint of water resources, Beijing has predominant power over Tianjin, and enjoys a higher priority in water resource allocation.

The case of Hebei Province reveals a quite different story. Geographically, it contains both Beijing and Tianjin. According to the Hebei Water Management Bureau, about half of the total outflow from mountain areas of the province goes to Beijing and Tianjin. Several large reservoirs constructed by Hebei Province for agricultural use, including the Miyun, Guanting, and Yuqiao dams, supply Beijing and Tianjin. As a result of the water-transferring project from the Luanhe River to Tianjin, the province supplies an additional 1 billion cubic meters of water annually to Tianjin. Such relinquishments of water rights result from administrative intercession which lacks proper compensation schemes. Another issue is untreated urban sewage, which is used for irrigation despite prohibition by the government, resulting in concerns about long-term health impacts. In addition, the total inflow of river water to the province has declined significantly, as indicated in Fig. 3. As a result, the already stressed demand-supply balance of water resources in Hebei Province has gone from bad to worse, and water resources problems have become a major limiting factor in the development of industry and agriculture.

A similar regional imbalance exists with water quality. Most river waters entering Tianjin are heavily polluted. Especially during times of drought, the city faces serious water shortages and water pollution problems. As a result, Tianjin City must deal with a much heavier burden than other cities to clean up pollution and improve its water environment. The fact that farmers in Hebei Province are using untreated urban sewage water from Beijing and Tianjin for irrigation is illustrative of the problems.

It can be seen that on the one hand, Tianjin City is the victim of Beijing's power, while on the other hand, the city is mitigating its losses by squeezing Hebei Province. Complaints have been persisting over this situation, especially in Hebei Province; several conflicts occurred since the 1980s, most of which ended with the triumph of Beijing. With no fundamental improvements on the horizon, these regional disputes are likely to continue for the foreseeable future.

2.3 Water Use: Sector-wise Use and Risks

Water use in Tianjin can be divided into agricultural and urban categories, and the latter one can be further divided into municipal, industrial and irrigation (for suburban vegetable field) uses. About half of the total urban water use in the city is for industrial purposes.

Per capita municipal water use in 1996 was 128 liters per day. This level did not increase much since 1984. However, the total non-agricultural population[2] of the city has increased from 4.3 million to 5.1 million over the period. This newly added urban population imposed greater pressure on the water supply system of the municipal government. With the improvement in household water supply and

[2] A part of urban population is still engaged in agriculture, and piped urban water supply is related only to the non-agricultural urban population.

sanitation facilities, popularization of the washing machine, and the development of service industries, it is highly possible that municipal water use will increase in the future. The major sources of municipal water are water transferred from Luanhe River and groundwater.The major water consuming industries are the chemical, machinery, petroleum, cotton spinning, paper production, food, and metallurgical industries. Although the amount of water used by these industries increased, due to improved recycling ratios since the beginning of 1980s, water withdrawal by these industries has not changed much. In 1984, the share of water supplied for industrial uses was 14.9% for river water, 27.5% for piped water and 57.6% for groundwater. Overexploitation of groundwater has resulted in a drop in the level of the water table over 60 m in the center of a depression cone. Excessive groundwater abstraction has also caused serious land subsidence over an adjacent area of 2,300 square kilometers (United Nations, 1997). The water recycling ratio reached 74% in the 1990s, equivalent to Japan's level; further improvements will be difficult since large investments will be required for only marginal further improvements. Tianjin's industrial production has grown by more than 10% annually; sweeping reforms in production technology as well as industrial structure are necessary if this trend is to continue without dramatic increases of water withdrawal. The growing Township and Village Enterprises usually have primitive technology and thus a very low water recycling ratio. This part of industrial water use is still small, but likely to grow significantly.

Agricultural water use is mainly covered by local surface water and groundwater. Because of the shortage of available water resources, urban sewage water is also used. In 1984, of a total of 1.629 billion tonnes of agricultural water use (including 239 million tonnes used for suburban vegetable fields), 42.5% were from surface water, 43% from groundwater, and 14.5% from urban sewage. According to a nationwide survey at the beginning of 1980s, the incidence of cancer and diarrhea in sewage irrigation areas was 0.3-0.5% and 1.4% higher than in other areas, respectively, and the mortality ratio by these two diseases was 0.02% higher (Haihe Water Resource Committee 1997). Despite the agricultural water shortage, irrigation water is still used wastefully and with low efficiency, due to leakage from old irrigation facilities, outdated irrigation methods such as flood irrigation, etc. The long-term heath risks of taking polluted agricultural products are a matter of concern.

Ecological water use is often neglected. A minimum amount of water is essential to sustain natural ecosystems and hydrological cycles, though the exact amount has not been clarified by research. Some changes in natural ecosystem are already noticeable in this area due to human overuse of water. In Bohai Bay, the decreased fresh water inflow from Haihe River has resulted in changes in marine fauna. Dropping groundwater tables accelerate aridity of the soil and lead to desertification. Such changes in natural ecosystems may eventually destroy the ecological foundations on which the city relies, and thus need more attention.

2.4 Output: Water Pollution

Pollution Discharge and Sources: According to 1995 data the total wastewater discharge from the city was 765.6 million cubic meters, with industrial wastewater accounting for more than 56%. The total chemical oxygen demand (COD) from urban urban effluent is 396,400 tonnes of oxygen, 72% of which is from industrial discharge. Major polluting industries include the chemical, brewing, paper mill, cotton spinning, food processing, leather manufacturing and pharmaceutical industries, accounting for 74% of industrial pollution discharge. About half of pollution comes from 6 districts in the center of the city.

Tianjin's Share of Pollution Discharge in the Haihe Basin: Table 1 shows the share of Tianjin City in water pollution discharge of Haihe Basin. Although Tianjin covers only 3.74% of total area of the river basin, its share in total pollution discharge is 18.4%, and COD discharge 16.74%. The average intensity of discharge of the Haihe Basin, calculated by dividing total discharge by area, is 13,100 tonnes per square kilometer, while for Tianjin it is 64,400, or 4.92 times the average level.

Table 1 Total Wastewater Discharge in Haihe Basin and the Share of Tianjin

Index	Area	Sewage Discharge	COD	Discharge per unit area: Wastewater	Discharge per unit area: COD
	(10^4Km^2)	(10^8m^3)	(10^4t)	(10^4m^3/Km^2)	(t/Km^2)
Haihe Basin	31.82	41.63	236.8	1.31	7.44
Tianjin City	1.19	7.66	39.64	6.44	33.31
Tianjin City/Haihe	3.74%	18.40%	16.74%	492%	448%

Data Source: Li, W. *et al* (1998)

Note: Li, W., et al, 1998. Plan for total pollutant load control in Tianjin. Research Paper of Tianjin Research Institute of Environmental Sciences. (in Chinese)

A similar tendency can be observed in the case of COD discharge. These numbers indicate that Tianjin's contribution to water pollution is quite high, and also that the city cannot solve water quality problems on its own.

Wastewater Treatment: In order to reduce its wastewater discharge, the city plans to improve its wastewater treatment capacity by expanding existing plants and constructing new plants. The daily treatment capacity of the Jizhuangzi Wastewater Treatment plant, the first urban sewage treatment plant in China, was expanded from 26 to 40 tons per day. In 1996 a new plant with the capacity of 40 tons per day was established in an eastern suburb. These two plants can treat up to 40% of the city's sewage discharge, but due to a lack of operating funds, the plants usually cannot be operated at full capacity. Currently the city is planning to build four more sewage treatment plants, two of which will be funded by the Asian Development Bank. Funding sources of the two other plants has not been found. While it is important to install this infrastructure, it is of vital importance to set up an effective financial mechanism to support the full operation of existing facilities, in order to improve water quality and reduce the amount of sewage used in irrigation and its negative consequences.

3 Review and Evaluation of Measures

3.1 Review and Future Perspective

Measures before the end of the 1970s: Flood disaster prevention was the most important task of water management from 1949 until the end of the 1970s. During the 10 years from 1964 to 1973, more than 30 waterways to discharge water more quickly to the sea were constructed and 35 medium to large reservoirs were either constructed or refurbished. These flood control measures prevented flood disaster in the Haihe Basin to a great extent. However, these projects also resulted in a great deal of alteration of the natural environment. Located at the lowest reaches of the river basin, Tianjin once had thousands of small lakes, marshes, and ponds because of the high groundwater level. Most of these have disappeared as a direct result of flood control projects and land reclamation under agricultural development policies. These shifted water storage functions from the lower to the upper reaches of the river. Many of these measures are now considered to have been shortsighted because they altered the natural ecosystem balance and lowered the flood water storage and resilience of nature. However, this perception is limited to scientists and is far from being reflected in policy measures.

In order to alleviate the problem of urban water deficiency, the city started to draw water from dams upstream as well as from other river basins. Following several trials of water transportation from Huanghe, a project to transfer water from Luanhe to Tianjin started in 1981. This project contributed greatly to the improvement of the demand-supply balance and the quality of drinking water in Tianjin.

Measures since the start of the 1980s: Since the beginning of the 1980s, with the rapid urbanization and industrialization of Tianjin and other areas in the basin, the emphasis of water resource management in Tianjin shifted to enhancement of efficiency in industrial water use, water conservation in municipal water use, and adjustment of the industrial structure.

(1) Water Conservation: Quotas were set for municipal water use, and water supplies were rationed. Efforts are being made to install a water meter in every household, and to replace toilet equipment with water-conserving designs. Due to these efforts, per capita daily water use in Tianjin was kept at a low level. Even more significant achievements have been made in industrial water use. The municipality administers a "Planned Water Use System", which includes penalties for water use exceeding the given quota. For water use exceeding quotas, enterprises are required to pay 2 to 10 times the normal rate for water. By introducing water conservation technologies, the water-recycling ratio was improved from 40% in the 1980s to 74% in the 1990s, the highest level in China, and comparable to Japan's level. During the 10 years from 1984 to 1994, water withdrawal per 10 thousand yuan of industrial production was reduced to one third the original level.

(2) Adjusting Industrial Structure: Since the surfacing of the problem of shortages of water resources the city has adopted an industrial development policy to control the development of large water using industries and allocate its limited resources more effectively. The share of some industries such as cotton spinning has decreased since the beginning of 1990s, while chemical, metallurgical, automotive and high tech electronics industries have grown steadily. The share of the six top water using industries (excluding Township and Village Enterprises) in total industrial output in Tianjin dropped significantly

from 55.4% in 1984 to 37.2% in 1997[3].

Future Perspectives of Tianjin's Water Resource Related Policies: According to estimates by the Tianjin Water Resource Bureau (1996), by the year 2010 the city will have a total water demand of 5.25 billion cubic meters while the water supply will be only approximately 4 billion cubic meters in a normal year, which means a water deficit of 1.25 billion cubic meters. This deficit will increase to 2.64 billion cubic meters in relatively dry years. Most of the water use increase will be in the industrial sector; water use is predicted to become almost three times the 1993 level, while the industrial output will grow to 9.6 times. The Bureau recommended the early construction of a major project to divert water from south to north, redirecting 14.5 to 23 billion metric meters of water annually from the Yangzi River, in addition to an expanded water diversion quota from the Luanhe, emergency water diversion from the Yellow River in drought years, and further development of local water resources including surface water and the use of seawater. There are arguments over viability as well as environmental impacts of inter-basin water transformation at all three geographical regions: the exporting region, the transfer region and the importing region (Liu et al., 1985; Caulfield, 1986), and further development of local water resources is impose more pressure to surrounding regions. While water transformation and temporary leasing of water rights may encourage more efficient water use and the trading of water into higher value uses, they must be carefully regulated, however, to ensure that water is not traded into inappropriate uses or out of systems that are already stressed (OECD, 1998).

3.2 Evaluation of Water Management Measures of Tianjin

Effectiveness: Fig. 5 shows the trends in water withdrawal per unit of industrial production in eight regions of the basin. With the exception of Neimeng (Inner Mongolia), water withdrawal per unit of industrial production has declined significantly, and the most recent figure for Tianjin shows the lowest level of all throughout the period of comparison.

It can be seen from the figure that industrial water use efficiency is improving, and yet large regional disparities exist. These disparities are closely related with geographical location. Water use efficiency tends to improve as one approaches the river mouth. This relationship might reflect the fact that the water resource constraints upstream are not as severe as downstream, and these constraints led to a greater improvement in resource efficiency of industrial production downstream such as in Tianjin.

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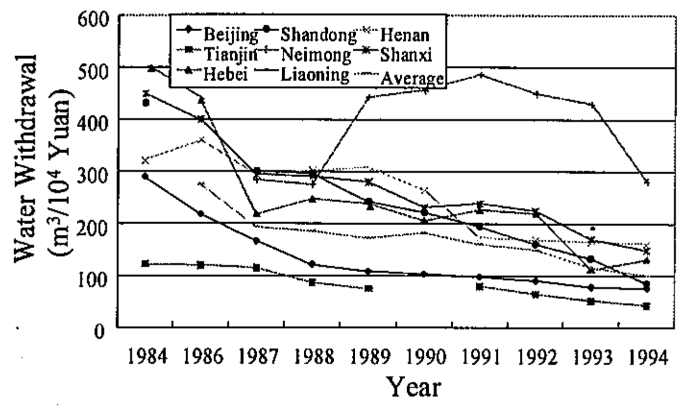
[3] calculated based on data from China Statistical Yearbook, 1997; Urban Statistical Yearbook of China, 1984-1995; Statistical Yearbook of Tianjin 1997 and 1998.

Fig. 5 Trends in Water Withdrawal Ratio per Unit Industrial Production in Haihe Basin



Data Source: Haihe Water Resource Committee (1997)

Long-term Vision and Policy Integrity: Until the end of 1970s, because water was perceived as the cause of natural disasters rather than as a precious resource, measures were more focused on flood prevention. Some of these flood control projects, especially construction of drainage waterways, played a negative role later in water resource preservation. A long-term development vision and comprehensive industrial planning was lacking in the past, as one can see from the existence of heavy water using industries in a region that has very limited renewable water resources. Since the economic, resource and environmental policies were not integrated at an early stage, the municipality was forced to deal in a haphazard way with water resource problems caused by rapid economic growth.

Equity: A ranking of priority in sector-wise water resource allocation can be recognized from Tianjin's case:from urban municipal water use at the top, to industrial, and then agricultural water use at the bottom. As discussed above, almost no water is allocated for agricultural use in the city, and much of the discharged urban sewage is used for irrigation. The problem of sector-wise water use equity links directly to the health risk of residents in the case of Tianjin. As a result, it warrants more attention. Inequity can also be observed in inter-regional resource allocation. Virtually no economic compensation is given to regions that provide water resources to other regions, and these allocations of water from one region to another are carried out by administrative order. Under the ranking system with Beijing at the top, followed by Tianjin and last of all Hebei Province, the people in the latter have strong perception of inequity. In the case of water quality, there is also a different kind of inequity. Because of its location at the lowest point downstream of the river, inflows to Tianjin are already heavily polluted , and posing a heavier burden on the city for water purification.

Institutional Arrangements: Complex administrative arrangements worsen the situation. More than 10 administrative bureaus, including a water resource bureau, environmental protection bureau, economic planning committee, financial bureau and others, are involved in water resource management. None of these are subordinate to another, nor can any of them play a leading role. In addition, the water-related jurisdiction of these bureaus is not clear in many cases. In the case of Tianjin, surface water in central districts and groundwater in suburban prefectures are managed by the water resources bureau, while the groundwater in central districts is under the control of the Urban Construction Committee of the city. Due to this artificial segmentation, water resources in the city can not be planned and managed as a whole. Most people are skeptical about the possibility of setting up a new administrative institution that has integrated supervision authority over water-related issue at the city level.

4 Implications of Tianjin Case Study

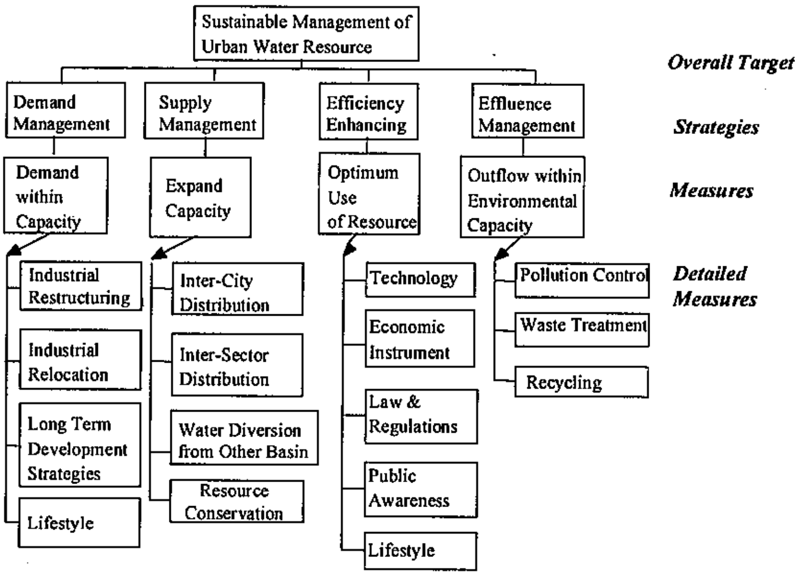
Typical of water-scarce cities in China, Tianjin's case reveals the complexity of urban water resource management, with many complex factors interacting. As Falkenmark (1999) pointed out, the developing world includes three phenomena in relation with water resource- escalating water competition, escalating dispute proneness, and escalating pollution load. At least two out of these three can be found in the case of Tianjin, and many other cities, especially those experiencing rapid economic growth and urbanization, are following similar paths. The most important lesson to be learned through Tianjin's case is that urban water management can not be carried out within the city alone, but rather requires a comprehensive systems approach including the natural hydrological cycle and socio-economic factors in a much wider regional context. Water resource and water pollution, resource capacity and demand management, and inter-regional relationships in resource allocation are three major issues which need to be addressed in relation with this systems approach. Concerning the latter issue, the necessity of cooperation between appropriate institutions has been recognized (Ostrom et al, 1999), and there seems a proneness to create institutions that facilitate cooperation (Falkenmark, 1999). In the case of Tianjin, the Haihe Water Resource Management Committee exists, but its administrative power is too weak to take on coordinating responsibility. Though the importance of these relations are recognized by scientists, there is very limited awareness of this at the municipal level, and this limited understanding is not reflected in actual management process in any way.

5 Strategies for Sustainable Water Resource Management

Management Framework: What can urban municipalities do to achieve sustainable water resource management? Based on the review of Tianjin's case, a framework of urban water resource management is drawn to provide a holistic picture of the issues and their relationships, while providing alternative choices for municipal decision makers to choose from. In drawing this framework, the following three aspects are considered important. Firstly, it is important to consider water resource management of cities in the context of watershed management approach, which has emerged as a holistic and integral approach, as the way of research, analysis and decision-making at a watershed scale (Montgomery et al., 1995). As argued by Voinov et al (1999), this certainly implies more than just the regional scale of analysis, but rather the necessity to integrate not only physical and biological factors, but also political and socio-economic ones. Secondly, rather than a mystical concepts of holism which often associated with a dangerous "top-down" thinking, the holistic view here means a limited, contextual holism. As argued by Norton (1991), a contextual holism is a systematic approach which sees the management problems from a local viewpoint or perspective, but recognizes also that any local perspective is limited, and that the problem must be understood also in its larger, systematic context, as a part of many larger "wholes". Thirdly, it is important to determine the ultimate goal or boundary of resource management (Lackey,1998), which determines the proper perspective and scale of the issue (Norton, 1991).

Here the ultimate goal is to achieve sustainable management of water resource of a certain city. The underlying methodology to achieve this ultimate goal is an integrated approach, not trying to address water resource issues in a single disciplinary context, but rather in an broader complex system including natural, social, and economic contexts. Under an overall target, four strategies -- supply management, demand management, efficiency management, and emission management -- can be adopted to achieve the overall goal. Under each of these strategies, the respective management targets should be to maximize resource input, keep demand within resource capacity, maximize the efficiency of use, and limit the discharge of pollutants within the environmental capacity. Each of these management targets can be achieved through various detailed measures. Fig. 6 shows the outline of such an overall framework.

Fig. 6 Framework for Sustainable Urban Water Resource Management



Implementation Regime: The above strategies should be implemented together as a whole in order to achieve sustainable water resource management goals. However, the actual situation cities face can be very different, and in many cases, measures tend to be concentrated in one or two categories that require less effort from inside and bring more immediate results. It is particularly true when there are regional disparity among cities that share the same water resources. For example, Tianjin City tends to adopt the first strategy -- to expand resource availability -- which can be seen from its past record and also future perspectives. This is because the other strategies either require much more laborious efforts or the benefits of the strategies are indirect, and that Tianjin City has the ability to take advantages over other surrounding regions. Asking cities or regions with different relative strengths and under evident conflicts of interest to solve the water resource management problem in a democracy seems impractical. Similar situation in ecosystem management has been likened to asking a pack of four hungry wolves and a sheep to apply democratic principles to deciding what to eat for lunch (Lackey, 1998). To deal with this situation, one might think of bringing someone who has supreme power to watch over the situation, educating and persuading the wolves to respect their fellow sheep and turn to vegetarian, watching the process carefully and get prepared to intervene if the wolves were to eat the sheep, and bringing in more sheep and other animals into the discussion to change the situation of four wolves versus one sheep. These suggest respectively the importance of: (1) institutional arrangement that can control and supervise the decision making process; (2) establishing water ethics which has to be up-to-date and based on an understanding of how the life support systems function (Falkenmark, 1999); (3) establishing effective monitoring, evaluation, and incentive as well as punishment system; and (4) increasing social involvement in the procedure; in water resource management. Only with these to ensure the implementation, can strategies become practical.

6 Concluding Remarks

This paper examined the water resource management issues in Tianjin, focusing on the major policy measures taken by the municipal government and the effectiveness of these measures. It has been found that cities are large contributors to water resource related issues, and their shares become increasingly important. Inter-sector water allocation inequity is significant. Shortage of agricultural water supply is causing the illegal use of untreated urban sewage, which might have risks to human health. The allocation of resources among the province and municipalities concerned is not rationalized, and the regional disparities in resource use efficiency are significant. Regions that are subject to stronger water resource constraints tend to achieve higher water use efficiency. Regional allocation of resources is a complex issue that needs an integrated approach of economic, social and institutional arrangements. Effective urban water resource management cannot be enforced by a single city, but rather requires a cooperative regional measures based on a systems approach with participation of a number of provinces and municipalities sharing water resources from the same water basin. In addition to traditional measures taken by cities, transformation of social and economic systems as well as the change in citizens' lifestyles is indispensable. A strong implementation scheme needs to be set up to ensure a sustainable urban water resource management.

References

Caulfield H Jr. 1986. Viability of Interbasin, Interstate/International Transfers of Water. *Water International* 11: pp. 32-37.

Falkenmark M. 1999. Forward to the Future: A Conceptual Framework for Water Dependence. *Ambio* 28 (4): pp.356-361.

Haihe Water Resource Management Committee 1997. Medium and Long Term Water Supply Plan of Haihe River Basin. Haihe Water Resource Management Committee:Tianjin. (in Chinese)

Lakey R. 1998. Seven Pillars of Ecosystem Management. *Landscape and Urban Planning* 40:pp. 21-30.

Liu Ch, Du W. 1983. Areal Reallocation of China's Water Resources. *GeoJournal* 10(2): pp. 157-162.

Montgomery R, Grant G E, Sullivan K. 1995. Watershed Analysis as a Framework for Implementing Ecosystem Management. *Water Resources Bulletin* 31: pp. 369-386.

Norton G B. 1991. Ecological Health and Sustainable Resource Management. In *Ecological Economcs: The Science and Management of Sustainability,* Costanza R (eds.). Columbia University Press: Newyork. pp. 102-117.

OECD 1998. Water Consumption and Sustainable Water Resources Management. OECD: Paris.

Ostrom E, Burger J, Field C B, Norgaad R B, Policansky D. 1999. Revisiting the commons: Local Lessons, Global Challenges, *Science* 284: pp.278-282.

Research Team on Water Resource in Huabei Region and Shanxi Energy Base, 1990. *On the Trend in Water Resource Demand in Jing-Jin-Tang Area and Strategies.* Report of the National Key Scientific Project of the 7th 5-year plan (project number 57). (in Chinese)

State Statistic Bureau Urban Socio-economic Survey Team 1984-1995. Urban Statistical Yearbook of China 1984-1995. China Statistical Publishing House: Beijing. (in Chinese)

Tianjin Municipal Statistical Bureau 1997. *Statistical Yearbook of Tianjin 1997.* China Statistical Publishing House: Beijing. (in Chinese)

Tianjin Municipal Statistical Bureau 1998. *Statistical Yearbook of Tianjin 1998.* China Statistical Publishing House: Beijing. (in Chinese)

Tianjin Water Management Bureau 1996. Medium and Long Term Water Supply Plan (1996-2000-2010). Tianjin Water Management Bureau:Tianjin. (in Chinese)

United Nations Economic and Social Commission for Asia and the Pacific. 1997. Study on Assessment of Water Resources of Member Countries and Demand by User Sectors: China: Water Resources and Their Use. United Nations: New York.

Voinov A, Costanza R. 1999. Watershed Management and the Web. *Journal of Envirnmental Management* 56: pp. 231-245.

Zhang D. 1989. On the Mischief of Transferring Water within the Region. In: *Proceedings of Workshop on Water Resource Demand and Supply Strategy of Hebei Province.* pp. 112-119. (in Chinese)