A MORE COST-EFFECTIVE STRATEGY FOR INDUSTRIAL POLLUTION CONTROL IN CHINA

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Abstract: From the viewpoint of econometrics, the aim of the study on the economics of industrial pollution in China is mainly to formulate a set of more cost-effective industrial pollution control policies. This paper covers the following aspects: (1) the environmental implications of sustainable economic growth; (2) the pollution reduction by structure adjusting plan; (3) the increase of incentive efficiency of pollutant charge; and (4) the more cost-effective investment for pollution control.

1.0 Environmental Implications of Sustainable Economic Growth

1.1 Sustainable growth of GNP in China

According to *the State's Social and Economic Development Plan for the Ninth-five-year Plan (1996~2000) and the Long-term Objectives for the Year 2010,* with the average annual GNP growth rate of 8% during the ninth-five-year plan period, the country's GNP will increase from 5760 billion yuan in 1995 to 8500 billion yuan[1]. Assuming the average annual GNP growth rate of 7.2% from 2001 to 2010, the country's GNP will be 17000 billion yuan in 2010. Furthermore, some international organizations, such as the World Bank, have also conducted rather longer period projection for the national economic development in China. Some long-and-medium term projection prospects for China's economic development are shown in Table 1.

Table 1   China's National Economic Development Projections

Author	*Indicator*	*1995*	*2000*	*2010*	*2020*
China Government	GNP(0.1 b yuan)	57600	85000	170000	n.v.
	GNP growth rate (%)		8(1995～2000)	7.2(2001～2010)	n.v.
World Bank	GDP(0.1 b yuan)	57600	86200	167990	286951
	GDP growth rate(%)		8.4(1995～2000) Agriculture: 3.1 Industry: 9.2 Service: 9.7	6.9(2001～2010) Agriculture: 4.2 Industry: 6.6 Service: 8.1	5.5(2011～2020) Agriculture: 3.7 Industry: 5.4 Service: 6.0
Li Jingwen, *et al.*	GNP (0.1 b yuan)	57600	88624	182656	N/A.
	GNP grow rate (%)		9.0(1995～2000)	7.5(2001～2010)	N/A.

Source: (1) *The State's Environmental Protection Plan for the Ninth-five-year Plan Period (1996~2000) and the Long-range Objectives for the Year 2010*, 1996. (2) World Bank, *New Century Challenge on Development: China in 2020*, 1997. (3) Li Jingwen, *et al.* China's Economy Facing the 21 Century, 1995.

It can be seen that there is no great difference among the long-and-medium term

[1] Calculated at the average exchange rate on July 1, 1998, i.e. 1 US dollar = 8.20 RMB yuan.

projections by different projectors, except that the World Bank presents prudent attitudes toward China's rapid sustainable GNP growth in the long term. The three projection values basically represent the low, middle and high growth speeds of GNP.

1.2 Environmental pollution from the economic growth

In both the Seventh-five-year Plan Period (1986~1990) and the Eighth-five-year Plan Period (1991~1995), the GNP pollution elasticity for all the main pollutants are under 0.6. Therefore, in the historical viewpoint, China's rapid economic development has not been accompanied with the in-step growth of pollution. Additionally, during the Seventh -five-year Plan Period and the Eighth-five-year Plan Period, both regional and national pollutant discharge intensities per unit GNP have obviously decreased. Considering the decrease of country-wide pollutant discharge intensity from the technical advancement and the descending effect of the technical advancement, the pollutant discharge rates per unit GNP are assumed at 4.5% and 3% respectively for 1995~2000 and 2001~2020 periods[2]. Simultaneously, the performance of environmental regulations and investment for pollution control are assumed to keep at the level of 1995.[3] Accordingly the potential industrial COD and SO_2 discharging pressures under 3 economic growth rates are shown in Figure 1.

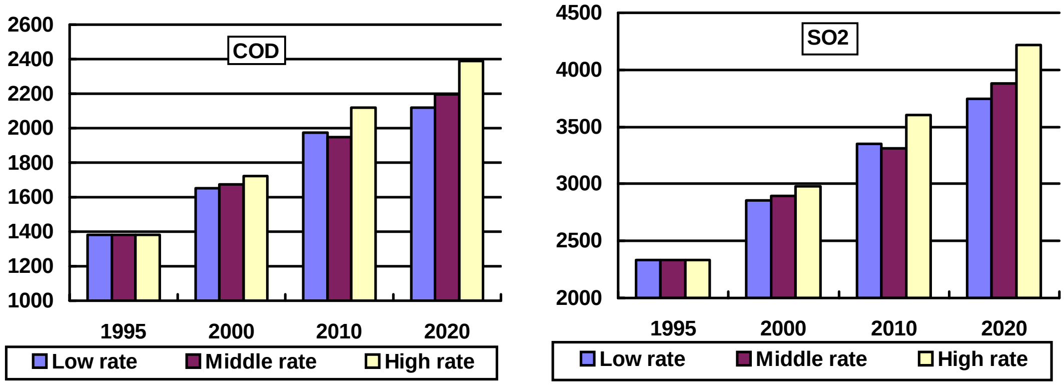

Fig. 1 Potential Industrial COD and SO_2 Discharges under Different Growth Rates (10000 t)

From the analysis of the above projection results, two conclusions can be reached. Firstly,

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[2] The comprehensive factors, e.g. technical advancement, energy structure adjustment and industrial structure change, are considered here. One most basic assumption is that the pollution intensity from new investments is obviously lower than that of old ones. However this kind of decrease rate of pollution intensity generally decreases with the scale of new investment. The discharge coefficient decrease rates are determined based on: (1) The COD and SO2 discharge intensities per unit GNP decrease by 6.3% and 5.0% respectively annually from 1986 to 1995. (2) The energy consumption coefficients per unit GNP decrease by 7.9% and 10.5% annually in the Seventh-five-year Plan Period and the Eighth-five-year Plan Period respectively. (3) The TSS、COD、SO_2 and SD discharge efficients per 10000 yuan GNP were respectively 0.027t, 0.037t, 0.041t and 0.069t (including TVEs) in 1995. Additionally, the State Government has planned to reduce the energy consumption efficient per 10000 yuan GNP by 5.0% annually in the Ninth-five-year Plan Period and the update of industrial structure and the technical advancement in the future up 20 years will be favorable to the environment.

[3] Since 1995 Chinese government has taken some strong measures to reduce industrial pollution, i.e., make regulations be more strict, closedown serious polluting small factories and increase investment on pollution. That is the reason why we call *potential* discharges here.

no matter which economic growth rate will be, the potential industrial pollution will by and large increase with the sustainable economic growth, especially obvious for the increase of SO_2. This is closely related to the energy structure in the next 20 years during which China still mainly depends on the coal for energy. Secondly, despite the overall increase of pollution, its increase rate will far lower than the GNP growth rate. Totally, the pollution will not increase synchronously with the economy[4].

1.3 Cost of pollution loss from economic growth

It is a very difficult and expensive work to comprehensively evaluate the environmental pollution loss from the economic growth. According to the World Bank(1997), in 1995, the economic loss of environmental pollution was between 23.3 billion yuan(bases on human-capital) and 53.6 billion yuan(based on the willing-to-pay), accounting for 3.5% and 7.7% of the year's total GNP respectively. Considering that this estimate has not included all the pollution losses, the potential environmental pollution risk resulted from the sustained economic development should not be optimistic.

1.4 Environmental impact of industrial structure

Limited to the data availability, the environmental impact of structure adjustment of secondary industry and tertiary industry are mainly analyzed here. Put Beijing, Shanghai, Guangzhou and Shenyang as examples, the urban industrial structures and pollution intensities of GNP in 1995 are described in Table 2. No stable correlation between the COD and SO_2 discharge intensities per unit GNP and the tertiary industry structure proportion can be seen in the table. From the viewpoint of COD, the enhancement of tertiary industry proportion (e.g. highly COD-polluted food and drink sector) can not decrease COD discharge intensity.

Table 2 Industrial Structure and Pollution intensity in Four Cities

City	*Beijing*	*Shanghai*	*Guangzhou*	*Shenyang*
GNP(10000 yuan)	13948900	24625700	12430697	6826485
Primary industry proportion (%)	5.8	2.5	5.9	13.2
Secondary industry proportion (%)	44.1	57.3	46.7	49.4
Tertiary industry proportion (%)	50.1	40.2	47.4	37.4
COD discharge (t)	73234	122878	56038	24768
SO_2 discharge (t)	382925	488564	140882	230496
COD discharge intensity(t/10000yuan)	0.0052	0.0050	0.0043	0.0036
SO_2 discharge intensity(t/10000yuan)	0.0275	0.0198	0.0113	0.0338

Source: (1) China Environmental Yearbook, 1996. (2) China City Statistics Yearbook, 1996.

Next we will focus on the effect of industrial structure adjustment on SO_2 discharge. Considering that coal combustion is the main source of SO_2, the pollution effect of industrial structure is analyzed from the coal consumption structure. Table 3 gives the

[4] Duo to the variations of assumed conditions, projection models and policy schemes, the projected industrial pollutant discharges do not completely comply with those in Chapter 4. But their growth trends are basically the same.

coal consumption and GDP structural proportions among different sectors in China in 1995. It can be seen that the energy or coal consumption coefficient per unit GNP of the secondary industry is much higher than that of the tertiary industry, with the former being 17.4 times the later. As the SO_2 discharge is in direct proportion to the coal usage, the SO_2 discharge intensity per unit GNP of the secondary industry is also much higher than that of the tertiary industry.

Based on the previous estimate, the average SO_2 discharge intensity per 10000 yuan GNP was 0.041 t in 1995. Assuming the direct proportion of SO_2 discharge intensities per 10000 GDP to coal consumption intensities for agriculture, industry and service, the SO_2 discharge intensities for 10000 yuan GDP of agriculture, industry and service are imputed at 0.00302t, 0.08053t and 0.00463t respectively. In addition, according to Li Jingwen(1995), China's future industrial structure development trend is described in Table 4.

Table 3 Coal Consumption and GDP of Three Industries in China

Industry	*Primary*	*Secondary*	*Tertiary*	*Total*
GDP(0.1 billion yuan)	11993	28538	17947	58478
GDP proportion(%)	20.5	48.8	30.7	100
Coal consumption(10000t)	1856.7	118010.5	4279.2	124146.4
Coal consumption proportion(%)	1.50	95.06	3.44	100
Coal consumption intensity (t/10000yuan)	0.155	4.135	0.238	2.2

Source: China Statistics Yearbook, 1996.

Table 4 Future GDP Structure in China

Industry Sector	*1995*	*2000*	*2010*
Agriculture	20	26.0	24.0
Industry	49	41.0	35.0
Service	31	33.0	41.0
Total	100	100	100

Source: Li Jingwen, et al. China's Economy Facing the 21 Century, 1995.

Based on the above projection results and the SO_2 discharge intensity coefficient of GDP in 1995, the SO_2 discharge intensities per 10000 GDP under different industrial structures in 2000 and 2010 are projected and shown in Table 5. It can be seen that, when considering the factor of technical advancement, the SO_2 discharge intensity of GDP decreases obviously with the time.

Table 5. Potential SO_2 Discharge Intensity of GDP in Consideration of Industrial Structure (t/10000yuan)

Scenario	*1995*	*2000*	*2010*
Without technical advancement	0.041	0.0353	0.0308
With technical advancement	0.041	0.0246 Agriculture:0.0021 Industry:0.056 Service: 0.003	0.0104 Agriculture: 0.00102 Industry: 0.02710 Service: 0.010

Therefore the potential SO_2 discharge under 4 different conditions can be projected[5](see Figure 2). Both the technical advancement and industrial structure adjustment have obvious effects on SO_2 reduction, with the effect of the former relatively bigger. The technical advancement and tertiary industry promotion are thus important policy measures for SO_2 reduction. This conclusion is not necessarily true for COD. But as long as the current policy of centralized sewage treatment is continued to implement, the structural adjustment of raising the service industry weight should also be favorable to the COD reduction.

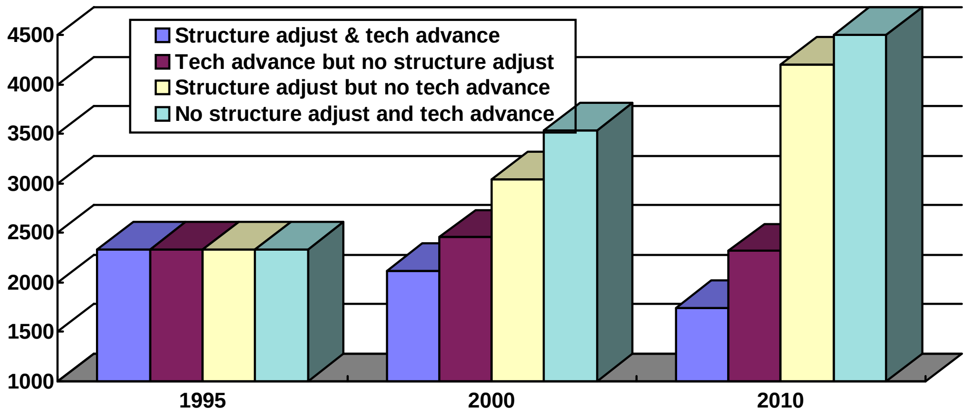

Figure 2. Industrial Structure and Technical Advancement And Potential SO_2 Discharge (10000t)

2.0 Pollution Reduction with Adjusted Planing

2.1 Impact of industrial growth rate

Based on the State's economic development planning, three sets of industrial development speed models are developed (Nian Liang. et al. 1998) and the pollution discharge status under different conditions projected using pollution demand function (Dong Cao, et al. 1998). The three sets of scenarios basically represent the high, middle and low speeds of industrial development, see Table 6. It should be noted that the 3 scenarios here do not correspond with the previous GNP growth rate. But as the industry is the core of national economy development, the industrial growth rate is generally higher than that of GNP.

Table 6. Industrial Development Projection in China

Years	*1996～2000*	*2001～2005*	*2006～2010*
High speed	14%	11%	11%
Middle speed	12%	9%	9%
Low speed	10%	7%	7%

[5] The SO2 discharge projection here is based on current energy structure and energy demand projection. The actual SO2 discharge may obviously be lower considering the future possibility of coal supply and the change of energy structure.

In the paper of *A Projection on Industrial Pollution Discharge and Abatement Cost in China*[6], three economic development and structure adjustment schemes (scenarios) are identified based on different targets. According to Scenario 2 in that paper (Nian Liang. et al. 1998), the potential COD and SO_2 discharge pressures in different periods without consideration of ownership reform and scale-economy effect are illustrated in Figure 3. Obviously in this circumstance the pollution discharge is in positive correlation with the industrial development speed.

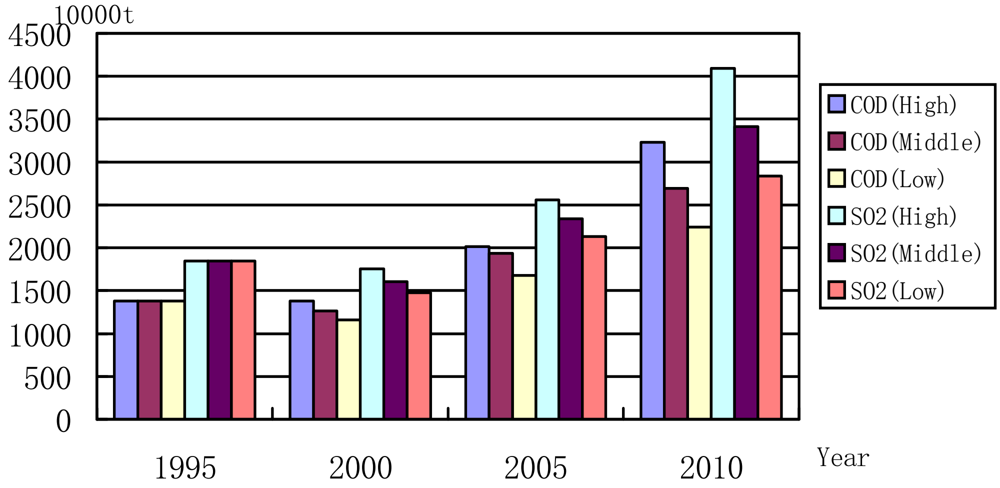

Figure 3 Industrial Growth and Potential Pollution Pressure (Reform Scheme)

According to the above projection, in premise of the State industrial adjustment policies and rapid industrial growth, potential COD and SO_2 discharges in average in 2010 are 2.13 times those in 1995[7]. Two conclusions can thus be reached. Firstly, huge pollution risk exists in the current industrial growth, and the industrial pollution situation in the early 21st century will be very severe if no effective cleaning measures are adopted. Secondly the industrial structure adjustment and technical advancement have great obvious roles in pollutant abatement.

Although the industrial pollution discharge is in direct proportion with the industrial growth rate, there is no great difference among the potential discharges under high, middle and low growth rates. Additionally, from the government decision-making viewpoint, the main factors controlling the industrial growth rate are the overall demand of national economic development as well as the macroeconomic performance, scarcely depending on the pollution prevention. In other words, although the low industrial growth rate is favorable to the pollution control in view of environmental protection, the high industrial growth rate is not necessarily a bad selection. It is thus concluded that the high

[6] This paper is based on the project, *the Economics of Industrial Pollution Control in China*, and compiled by Nian Liang, Zhihong Liu and Xiulan Gao.

[7] The projection premise is still without change of current industrial structure and does not consider the possibility of energy supply and change of energy structure in the long term. This kind of projection is thus of a warning one.

growth scenario can be selected as long as with reasonable industrial structure and depending on technical advancement and cleaner production. However, GNP growth and industrial development in China are slowing down because of the expanding influence of Asian financial crisis.

2.2 Reducing Pollution by Industrial Structure Adjustment

For convenience, we choose the middle scheme of industrial growth rate (i.e. 12% before 2000, 9% after 2000) and the three schemes (both Scheme 2 and 3 being adjustment schemes[8]) proposed by Nian Liang, et al. for consideration of industrial structure adjustment. A slight variation is that we suggest the same effective pollution levy intensity of Scheme 2 and 3 as that of Scheme 1. Therefore using the pollution demand function[9], the potential COD and SO_2 under the current effective pollution levy intensity (EPLI)[10] (COD, 0.08yuan/kg; SO_2, 0.043yuan/kg) can be projected and showed in Figure 4.

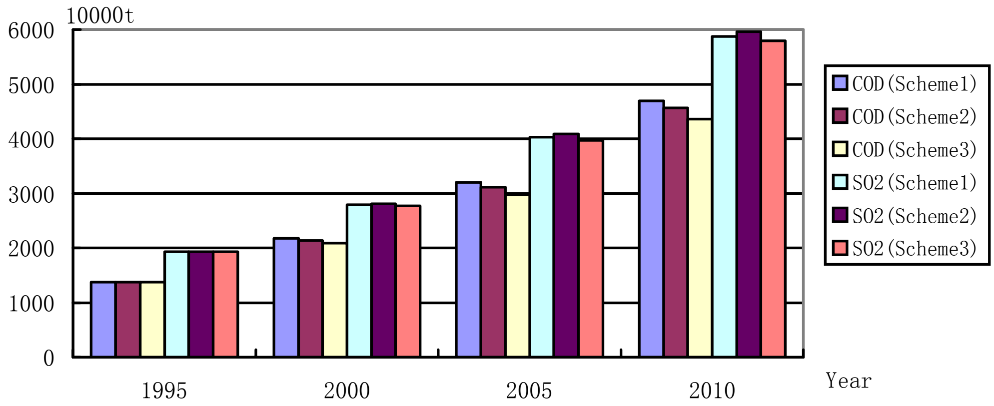

Figure 4 Impact of Industrial Structure Adjustment on Potential Industrial Pollution

It can be seen that the industrial structure adjustment has somewhat impact on the potential industrial pollution. As Scheme 2 basically depends on the Government's planning of national economy and industrial structure adjustment, with the development focus on the sectors with large SO_2 discharge and small COD discharge, it has slightly more potential SO_2 and less potential COD compared with Scheme 1. For Scheme 3, it is an environmental protection oriented industrial structure adjustment scheme, with development of some serious-polluted industrial sectors to be controlled, and the corresponding potential pollution are lower compared with Schemes 2 and 1.

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8 It should be noted that the main difference between Schemes 2,3 here and the Schemes 2,3 proposed by Liang Nian et al is that of EPLI. The EPLIs of Schemes 2 and 3 by Liang Nian, et al are 1 and 2 times those of Scheme 1. Therefore under the same industrial growth rates, without increase of EPLI, the projections in Figure 4 are obviously higher than those in Figure 3 for the corresponding scheme (e.g. both for Scheme 2).

9 The environmental demand function is based on the project, *the Economics of Industrial Pollution Control in China*, and developed by the Dong Cao of Chinese Research Academy of Environmental Sciences (CRAES).

10 EPLI is the actual average pollution levy burden for unit pollutant discharged. EPLI is usually obviously lower than the charge rates due to the variation of enforcement of regulations.

It can be concluded from the above analysis that the suitable control on the obviously polluted industrial sectors with large pollution loads could facilitate to alleviate the rapid increase trend of industrial pollution. This involves metallurgical, chemical, non-ferrous metal, power and building materials industries. However, as pointed out above, the industrial structure adjustment is dependent more on the State industrial policies. It is thus more feasible to analyze the environmental impacts for various alternatives in the formulation of the State industrial policies, so as to formulate *greener* industry policies favorable to the environment. And furthermore, as shown in Figure 3, the realization of total quantity control target in 2000 can not completely be realized only by industrial sector structure adjustment.

2.3 Environmental effect of raising industrial scale

According to the econometric analysis on enterprise polluting behaviors[11]， there are two main aspects of pollution discharge effect of enterprise scale: Firstly the enterprise scale directly affects the pollutant discharge per unit output or the pollution discharge intensity. Secondly it indirectly affects the pollution treatment efficiency and the treatment cost or marginal abatement cost (MAC). Figure 5 gives the variation characteristics of COD and SO_2 MAC with the change of enterprise scale. The MAC of small enterprises is obviously higher than that of large and medium ones.

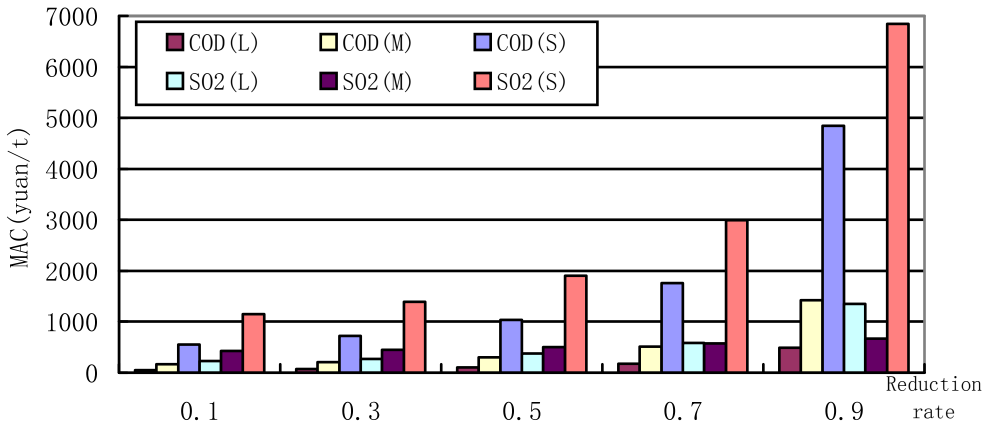

Figure 5 Impact of Enterprise Scale on Marginal Abatement Cost

In order to analyze the impact of enterprise scale on pollution discharge, we project the potential COD and smoke dust discharge trends under 4 enterprise scales for Scheme 2 (assuming EPLI of 0.08 yuan/kg for COD and 0.01 yuan/kg for smoke dust) using pollution demand function. See Figure 6 for details[12]。

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[11] Refer the econometric analysis conclusions to *the Econometric Analysis on Industrial Enterprise Pollution Behaviors in China* (Dong Cao, et al., 1998).

[12] According a survey in the Industrial Economy Institute, the Chinese Academy of Social Sciences, there are 4 possible trends of enterprise scale development in China: i) keeping the country's current enterprise scale level, with the industrial added values (IAVs) of large-and-medium enterprises (L&MEs) in 2000 and 2010 keeping at 1995

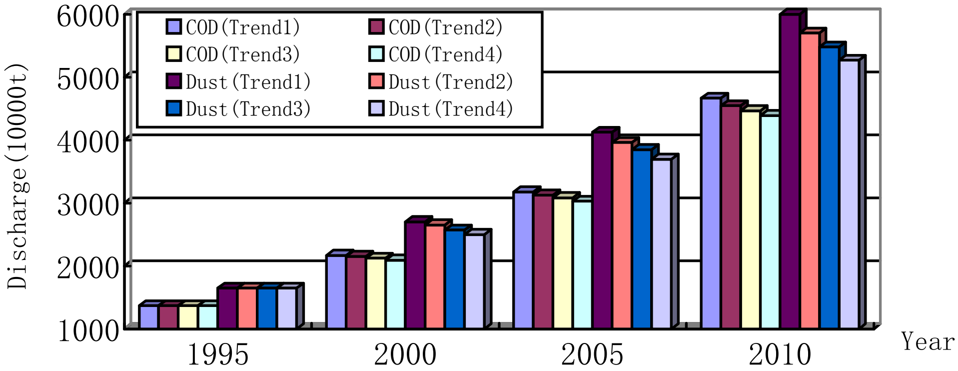

Figure 6 Impact of Enterprise Scale on Potential Pollution Pressure

From the above projection, for both COD and smoke dust, the bigger the enterprise scale, the smaller its pollution discharge intensity. Therefore from the viewpoint of reducing industrial pollution discharge intensity, the increase of industrial enterprise scale is a *win-win* policy of reducing the pollution as well as increasing the economic efficiency.

2.4 Environmental Impact of Enterprise Ownership Reform

Both the World Bank experts and Chinese experts have studied the relationship between the enterprise ownership and the industrial pollution, despite that their conclusions are not completely the same. The World Bank experts found that non state-owned enterprises (SOEs) have great advantages in aspect of pollution abatement cost. However, Chinese experts did not find the obvious correlation in the view of the whole country[13].

According to the findings of the World Bank (Susmita Dasgupta, et al. 1997), the pollution MACs for enterprises of different ownership are greatly different. For SO_2, with the abatement efficiency of 90%, the MAC of large SOEs is US $280/t while the value is only US $50/t for large non-SOEs. The MAC of small SOEs is US $5500/t and only US $1000/t for small non-SOEs. The average SO_2 MAC of SOEs is thus 5.55 times that of non-SOEs. They concluded that the ownership reform toward the non-SOEs would be favorable to industrial pollution abatement, at least able to obviously reduce the pollutant abatement cost.

From the proportions of IAV, the economy of non-SOEs has overridden that of SOEs, with its proportion having increased from 42% in 1988 to 52.9% in 52.9%. In the

level(56%); ii) slow growth, with IAVs of L&MEs accounting for 58% and 62% in 2000 and 2010 respectively; iii) middle growth, with IAVs of L&MEs accounting for 61% and 66% in 2000 and 2010 respectively; iv) rapid growth, with IAVs of L&MEs accounting for 64% and 70% in 2000 and 2010 respectively.

[13] As most enterprises are L&MEs in the industrial pollution database developed by the CRAES experts, part of systematic deviations may occur accordingly in the result.

projection by Susmita Dasgupta and Hua Wang, the non-SOE economy would exceed the SOE economy after 2005, with the proportion of 52.5% and 57% respectively in 2010 and 2020. This projection may underestimate the ownership reform process of enterprises in China. For simplicity, we assume that the proportion of the non-SOEs will reach 55%, 60% and 65% in 2000, 2005 and 2010 respectively.

In order to estimate the industrial pollution abatement cost savings from the enterprise ownership reform, the following assumptions are proposed: (1) one the base of the MAC under the abatement efficiency of 90% and only in consideration of SO_2 reduction; (2) not considering the impact of ownership on industrial pollution discharge intensity; (3) adopting the reduction projection results of *A Projection on Industrial Pollution Discharge and Abatement Cost in China* (Nian Liang, et al. 1998) as the SO_2 reductions in the targets years; (4) not considering the difference of MACs among different industrial enterprise scales, with the average value of US $2576/t for SOEs and US $468/t for non-SOEs; (5) the proportion of non-SOEs in 1995 as the Base Case for ownership comparison; (6) the industrial growth rate of 12% and industrial sectoral structure of Scheme 1. Therefore the possible decrease of pollution abatement cost from the future ownership reform can be calculated, shown in Table 7.

Table 7 Possible Decrease of SO_2 Abatement Cost from Ownership Reform

Item	*2000*	*2005*	*2010*
Anticipated reduction(10000t)	1205	3269	6412
Reduction load under current ownership(10000t)			
SOEs	567	1539	3020
Non-SOEs	638	1730	3392
Reduction load under reformed ownership(10000t)			
SOEs	542	1307	2744
Non-SOEs	663	1962	4168
Abatement cost under current ownership (billion Us dollars)	17.5	47.7	93.7
Abatement cost under reformed ownership (billion Us dollars)	17.0	42.8	90.1
Saving from ownership reform (billion Us dollars)	0.5	4.9	3.6

It can be seen that the potential SO_2 abatement cost saving from enterprise ownership reform is obvious. Because the gap of SO_2 MACs between SOEs and non-SOEs increases with the increase of the SO_2 reduction rate, the SO_2 abatement cost and the corresponding saving will decrease with the decrease of SO_2 reduction rate. On the other hand, if considering the impact of ownership reform on pollution discharge intensity, the above saving of SO_2 abatement cost will even increase. Therefore the ownership reform toward private enterprise development is again a *win-win* policy of reducing the pollution as well as increasing the economic efficiency. In the long run, the current enterprise system reform is favorable to the environmental protection, at least providing a sound circumstance for introducing market based instruments for pollution control.

3.0 Increasing Incentive Efficiency of Pollution Charge

The current main economic instrument in China's environmental management is pollution charge. A good pollution charge system designed and implemented may create a *win-win* effect of environment and economy. In this section, on the base of an analysis of EPLI impact on industrial pollution intensity, the requirements of pollution charge reform to realize the country's total quantity control targets will be proposed.

3.1 Current Incentives of Pollution Charge

For the main charge for water pollution, the charge for superstandard concentrations is currently implemented, i.e. to calculate the wastewater charge amount on the base of the superstandard multiple of discharged pollutant times the volume of wastewater discharged. It is thus very difficult to determine the charge criteria for unit pollutant. The average EPLIs of four pollutants from county-and-upper enterprises as well as all enterprises of the whole country in 1995 are calculated and shown in Table 8.

Table 8 Effective Total-quantity Pollution Levy Intensity in 1995

No.	Pollutant	County and upper Enterprises		All-country average Enterprises	
		EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)
1	TSS	0.3	814	0.08	1563
2	COD	0.25	768	0.08	1380
3	SO_2	0.07	1405	0.04	1846
4	Dust	0.08	838	0.01	1687

There is obviously a great gap of EPLIs between the county-and-upper enterprises and the enterprises of the whole country, due to the weakness of the environmental management for township-and-village enterprises(TVEs). In view of the relationship between EPLI and pollutant discharge, the county-and-upper industrial enterprises have EPLIs higher than the country's average value and thus have obviously better pollutant discharge control.

3.2 EPLI to Achieve Total-quantity-control Targets

Three projection schemes are proposed, in which Scheme 2 is based on China's planning of economic development and structure adjustment and fits to the actual situations. Based on this scheme, we will analyze the impact of different levels of pollution charge incentives on COD and SO_2 discharge.

Firstly, we assume three schemes for the change of EPLI, i.e. keeping the current status, annual increase of 10% and annual increase of 20%. Using the pollution demand function (Dong Cao, et al., 1998), the relationship between COD and SO_2 levying intensity and the corresponding pollutant discharge is obtained, shown in Figure 7.

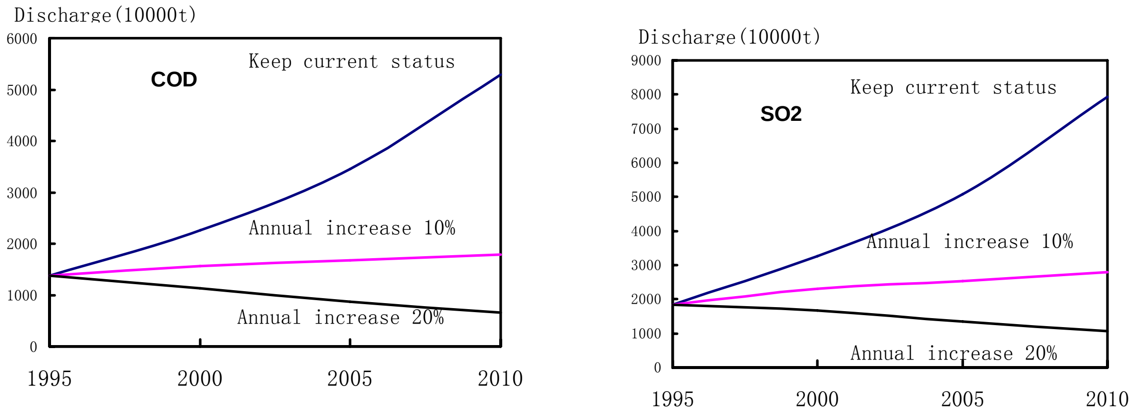

Figure 7　Impact of Different EPLIs on potential COD and SO_2 discharge

It can be seen from the figures that the pollution charge plays an obvious role in pollution discharge control. In the future 15 years, in order to keep the environmental quality at the 1995 level while having a high economic development speed, pollution charge incentives should be highlighted, with the EPLI raised step by step. If the EPLI increases by 10% annually on the base of 1995, the COD and SO_2 discharge in 2010 will basically keep at the 1995 level or slightly greater. If the annual increase rate of EPLI is 20%, the discharge of the two pollutants will decrease obviously, with corresponding environmental improvement. This variation of pollution control ability of different EPLIs should provide basis for the exact EPLIs for different environmental protection objectives. Figure 8 gives the COD and SO_2 discharge situations under different EPLIs in 2000 and 2010. It is noted that the main policy variable in pollution demand function is the pollution charge system and other policy factors are difficult to be quantified, therefore the actual pollution-abatement incentive of pollution charge may be lower than that projected by us. According to the study by the CRAES, in order to realize the up-to-standard discharge objective in 2000 utilizing pollution charge, the current pollution charge rates should be 4~6 times higher (Jintian Yang, et al., 1998).

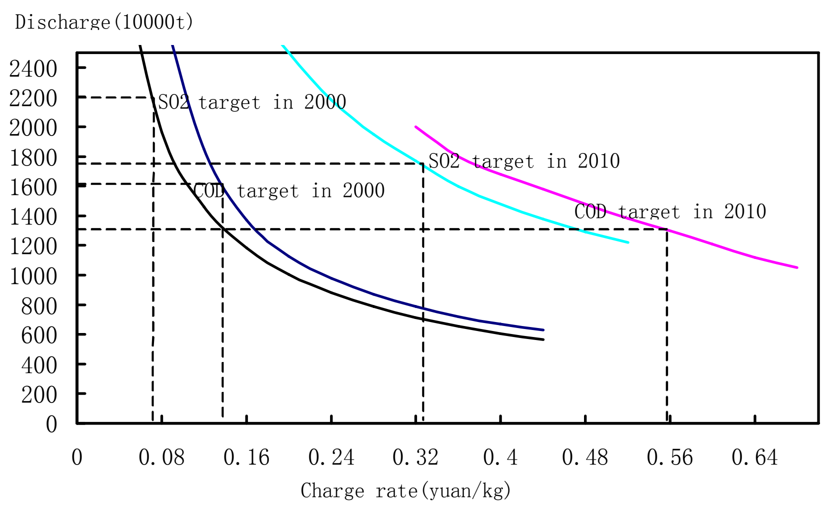

Figure 8　　Impact of Different EPLIs on Potential Pollutant Discharge

According to the objective proposed by the State Environmental Protection Administration(SEPA), the discharge of main pollutants in 2000 should be controlled at the 1995 level, and by 2010, ‘trying to basically control the deterioration trend of environmental pollution and ecological disruption, making environmental quality of part of the cities and areas to be improved’. Therefore we identify the control targets of main pollutants in 2005 as decrease by 10% on the base of 2000, and the targets in 2010 as decrease by 20% on the base of 2000. In order to achieve this objective, the COD EPLIs should be 0.14yuan/kg and 0.56 yuan/kg in 2000 and 2010 respectively, and the SO_2 EPLIs should be 0.07yuan/kg and 0.33 yuan/kg respectively.

Currently the SEPA has formulated a series of pollution charge reform schemes. The demonstrations of the new total-quantity pollution charge have started, with three pilot cities(Hangzhou, Jilin and Zhenzhou). The pilot COD levying standards are 0.4~0.7yuan/kg， with SO_2 being 0.32~0.63yuan/kg. It can be seen that there has been a great increase range of charge rate for COD. If this charge rate is completely implemented (that is to say the EPLI equals to charge rate), the COD discharge will be obviously reduced. In the short term, the COD EPLI target of increasing from 0.08yuan/kg to 0.7yuan/kg (or the charge rate of 1.4~2.8yuan/kg) should be reached step by step. Furthermore, the current SO_2 charge rate in two provinces and nine cities as well as in *the two control zones*[14] is 0.2yuan/kg. If the new rate (0.63yuan/kg) is fully levied, it will obviously be favorable to the realization of SO_2 control target in 2010. Table 9 is the required EPLI and the pollutant discharge in the target years to achieve the environmental protection objective.

Table 9 EPLI to Achieve Pollution Control Objective

Pollutant	2000		2005		2010			
	EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)
COD	0.14	1600	0.27	1440	0.56	1280	0.7	1018
SO_2	0.07	2200	0.16	1980	0.33	1760	0.2	2450

3.3 EPLIs in Different Sectors

Figure 9 gives the COD discharge levels for the main polluting industries in different years when the EPLIs is increased by 20% annually.

It can be seen that with the gradual increase of EPLIs, there is a decreasing trend of COD discharge for main polluting industries. However obvious difference exists among various industries under the same levying incentive. For paper-making and food product industries with large COD discharge, the discharge obviously decreases with the increase

[14] Two control zones means the areas of SO2 emission control and acid rain control, which was defined by the Sates Council in 1998 and covers 11.4% of the territory of China.

of the EPLI, showing their sensitivity to the levying. In other words, the increase of EPLI will effectively reduce the potential COD discharge in the two industries.

For SO_2, the discharge projection of different industries is given in Figure 10. The main control target is electric power, steam and hot-water production and supply industry, with its SO_2 discharge much higher than that of other industries. From the curve slop ratio of the sector discharge change with the EPLI, this industry is most sensitive to the increase of EPLI and thus the ideal control target by pollution charge. Among other main polluting industries, the non-ferrous-metal metallurgy and calender processing industry has the least discharge and least sensitive to pollution charge as there is enough benefit from reusing SO_2 in these industries. The chemical industry and building materials industry are less sensitive compared with the food product industry and the non-ferrous-metal metallurgy and calender processing industry, although their SO_2 discharges are near to each other. Generally speaking, the four industries are not very sensitive to the increase of EPLI with gentle curve slope ratio. Therefore the SO_2 control by pollution charge will be mainly embodied on the power industry. This conclusion is extremely in accordance with the actual key industry for SO_2 charge and abatement.

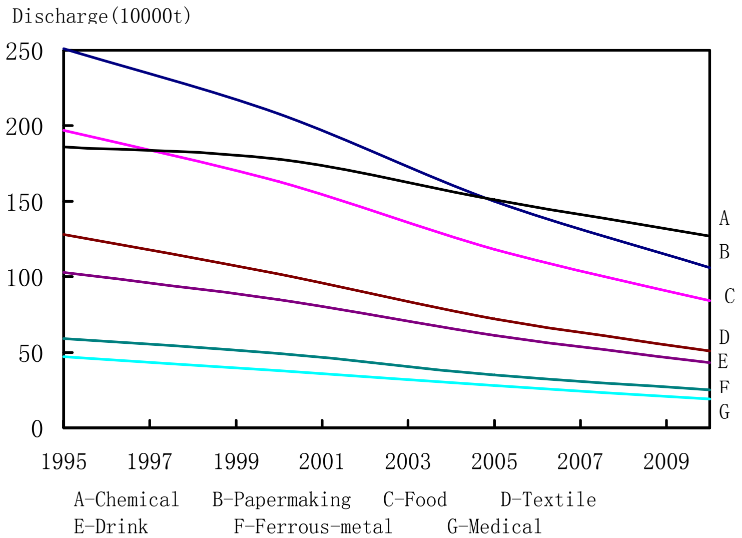

Figure 9　Main Industries COD Discharge with Annual EPLI Increase by 20%

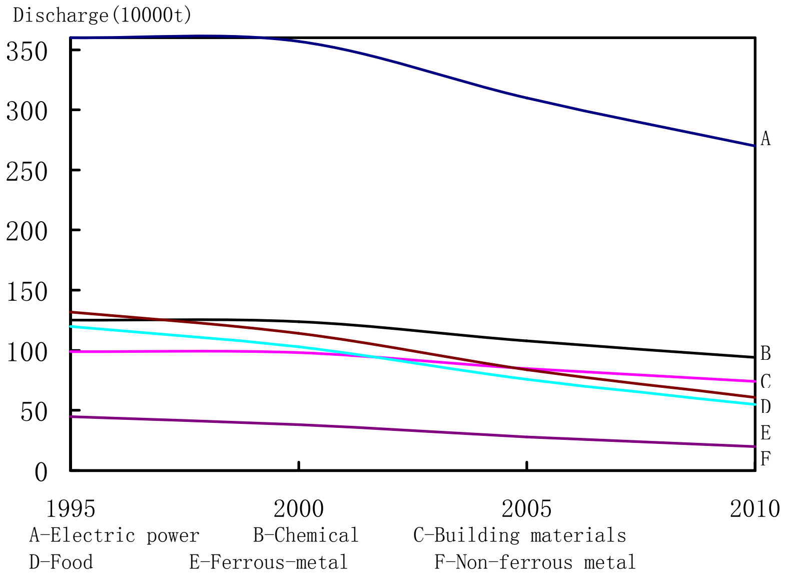

Figure 10 Main Industries SO_2 Discharge with Annual EPLI Increase by 20%

According to the above analysis, if EPLI increases with the annual rate of 20%, the requirements for environmental protection objective of pollutant discharge will basically be complied with. However, different pollutants and different industries are not with the same sensitivity. The same levying incentive will play greater roles in COD abatement than SO_2. And paper-making industry and power industry as the main polluting industries of COD and SO_2 are more sensitive compared with other industries. The pollution charge is thus a good instrument for controlling industrial pollution.

4.0 Cost-effective Pollution Investment Planing

4.1 Long-and-medium term industrial pollution control cost

The current long-and-medium term environmental objective involves two aspects, i.e. pollutant total quantity control target and enterprise pollutant up-to-standard discharge target. In order to realize the total quantity control target in 2000, the total increased investment[15] for COD、TSS、SO_2 and dust treatment will be 55.39 billion yuan during the ninth-five years, which is 0.67% of industrial output value of the year 2000. In order to realize the total quantity control target in 2005, the total investment for treatment of the four pollutants will be 93.75 billion yuan during the tenth-five years, or 0.74% of industrial output value of the year 2005. In order to realize the total quantity control target in 2010, the total investment will then be 146.42 billion yuan during the eleventh-five years, or 0.75% of industrial output value of the year 2010 (Nian Liang, et al., 1998).

Another environmental protection target formulated by the State Government is that all

[15] The investment here means the capital funds for installing equipment and constructing infrastructures, not including operation cost of pollution abating facilities.

enterprise pollutant discharges should meet with the national discharge standards in 2000. How much investment it requires is a problem concerned by the related governmental departments. Now we will use pollutant treatment cost functions provided by econometric analysis to analyze the required abating cost when discharges from all the current pollution sources meet with the national discharge standards (or compliance discharge)[16].

According to a survey on pollutant up-to-standard discharge situations conducted by the State Environmental Protection Administration (SEPA) in 1996, the compliance rate with the wastewater comprehensive discharge standard was 49.3%, while the that for boiler air- pollutants discharge standard and coal-fueled power plants air-pollutant discharge standard (exclusive of SO_2) is respectively 75.3% and 78%, with the average of 77%. In 1996 the countrywide county-and-upper industrial wastewater discharge and industrial waste gas discharge are 20.6 billion t and 11119.6 billion m^3. According to the data provided by econometric study (Dong Cao, et al., 1998), for one *typical* industrial enterprise wastewater treatment facility or waste gas treatment facility in China, the annual average water discharge and waste-gas discharge are about 0.20million t (550t/d) and 0.03billion m^3 (82000m^3/d) respectively. The wastewater treatment facilities and waste gas treatment facilities required for up-to-standard discharge of county-and-upper enterprises are then calculated at 103000 and 370000 sets respectively. Additionally, the abating cost[17] of one set *typical* wastewater treatment facility for national Class II standard discharge is 0.386 million yuan and that for waste gas for current discharge standard is 0.427 million yuan, with the total of 0.813 million yuan.
Based on the above compliance rate, the cost for COD and TSS up-to-standard(Class II) discharge from all county-and-upper enterprises in China is 20.16billion yuan, and that for dust and SO_2 is 36.34billion yuan. The total is 56.5 billion yuan, accounting for 0.84% of GNP of the year 1996. It should be noted that this value is only for four pollutants in existing county-and-upper enterprises. According to the countrywide survey on TVEs pollution sources by SEPA, there were 1.216 million TVEs pollution sources in 1995 in China, with the discharge of some pollutants having accounted for about half of the country's total industrial discharge. The technical level of TVEs is generally low, the pollution treatment facilities not perfect, and the compliance rate obviously less than that of county-and-upper enterprises. Therefore, the cost for up-to-standard discharge of all existing TVEs should be very high. However, we can not quantitatively estimate the exact cost demand for up-to-standard discharge of TVEs due to the limit the data.

4.2 Investment-effective discharge standards

According to the database developed by the CRAES, the enterprise COD compliance

[16] Strictly speaking, the compliance discharge here means the one single pollutant such as COD or SO2 meet with the comprehensive standard. The discharge of other pollutants is not considered in this study. According to the situation in the Huaihe River basin in China, the cost for compliance of all the pollutants is more than double of that for single COD compliance.
[17] The abating cost here covers the direct operation cost (such as the costs of electricity, agent and salary of workers) and depreciation of investment on pollution abating facility.

situation corresponding to different COD discharge standards are shown in Figure 11.

From Figure 11 it can be seen that the enterprise COD discharge compliance rate gradually increases with the decrease of its discharge standard. With the standard of 50mg/L, only 14% enterprises meet with the standard, and when the discharge standard decreases to 600mg/L, about 83% enterprises can meet with the standard. Under the current Class II COD discharge standard, the enterprises' COD compliance rate is 48%. When the pollutant compliance rate varies with the discharge standard, the cost for all the enterprises to meet with the discharge standard also changes. Table 10 gives the industrial enterprise compliance rate and the cost for all the enterprises to meet with the discharge standard under different COD discharge standards (with 103000 sets of wastewater treatment facilities required).

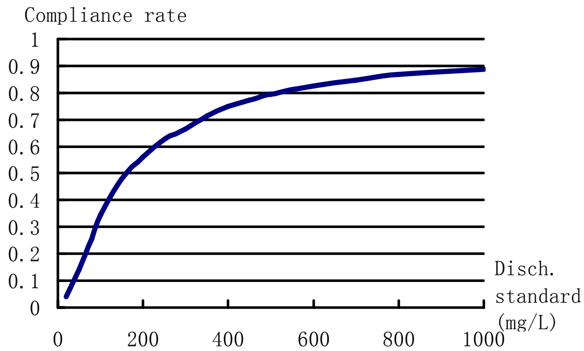

Figure 11 COD Discharge standard relationship with enterprise compliance rate

Table 10 Compliance-for-all Cost Variation with COD Discharge Standard

Discharge standard (mg/L)	Compliance rate of enterprises (%)	Abating cost of *Typical* facility (10000yuan)	Abating cost of compliance-for-all enterprises (0.1 billion yuan)	Difference with abating cost under current standard (0.1 billion yuan)
50	14	23.0	203.7	+95.5
100	35	21.2	141.9	+33.7
150(current Class II)	48	20.2	108.2	±0
200	56	19.6	88.8	-19.4
300	67	18.6	63.2	-45.0

From the viewpoint of cost demand of a single enterprise wastewater treatment facility, the difference between cost demand for 300mg/L COD discharge standard and that for 150mg/L standard is 16000 yuan. And the difference between cost demand for 100mg/L standard and that for 150mg/L standard is 10000 yuan. Thus in respect of pollution treatment, the current 150mg/L COD standard is relatively suitable for Chinese enterprises.

On the other hand, if the discharge standard increases from 150mg/Lto 100mg/L, only additional 10000 yuan is required for one set of treatment facility, which is bearable for most enterprises. Therefore the standard may be further stricter. However, although increase of discharge standard does not mean an outstanding cost for single enterprise, for the scope of the whole country it should be a heavy burden as 3.37 billion yuan more will be input for all the existing county-and-upper enterprises to meet with the higher standard.

In summarization, the current COD Class II standard is a suitable standard and under the current situation the discharge standard should not be stricter. From the viewpoint of pollution reduction, treatment cost and enterprise's bearing capability, there is a possibility to increase the standard from 150mg/L to 100mg/L.

According to 3000 key pollution sources of the State identified by China Environmental Monitoring Center (CEMC), the relationship between SO_2 discharge standard and the abatement cost for all enterprises to meet with the standard can be analyzed. The CEMC data mainly are for the key SOE pollution sources in China and only reflect the situation of those county-and-upper enterprises. See Figure 12 for the enterprises compliance rate variation with SO_2 discharge standard.

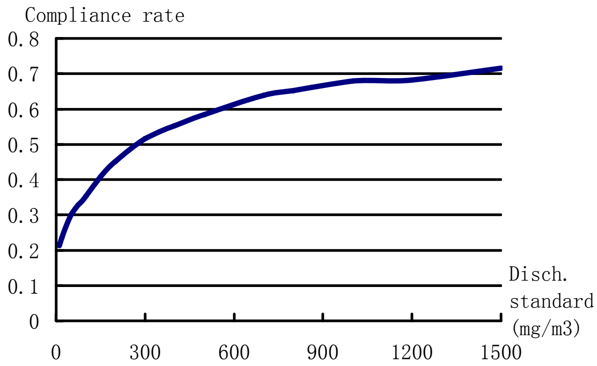

Figure 12 SO2 Discharge standard relationship with enterprise compliance rate

From Figure 12, it can be seen that the enterprise SO_2 discharge compliance rate increases gradually with the increase of SO_2 discharge standard. But compared with COD, the impact of the standard variation on the compliance rate is less. Also, the distribution of SO_2 compliance rate is relatively uniform. With the discharge standard increase from 20mg/m^3 to 1500mg/m^3, the enterprise compliance rate will increase from 20% to 70%. With SO_2 discharge standard of 300mg/m^3, 51% enterprises will meet with the standard. When the standard decreases to 1000mg/m^3, 68% enterprises will meet with the standard. This change of compliance rate is not obvious. Under the current SO_2 discharge standard, the compliance rate will be 64%. With the change of pollutant compliance rate with the discharge standard, the cost demand for all the existing enterprises to meet with the standard will also change. According to the database sampling analysis, the *typical* SO_2 treatment facility scale of existing county-and-upper enterprises is 140 t SO_2 annually. If calculated at the 13.64-million t industrial SO_2 discharge in 1996, 100000 sets of SO_2 treatment facilities are required. Table 11 gives the industrial enterprise compliance rate and the cost for all county-and-upper enterprises to meet with the discharge standard under different SO_2 discharge standards.

Table 11 Compliance-for-all Cost Variation with SO_2 Discharge Standard

Discharge standard (mg/m^3)	Compliance rate of enterprises (%)	Abating cost (10000yuan)	Abating cost of compliance-for-all enterprises (0.1 billion yuan)	Difference with abating cost under current standard (0.1 billion yuan)

50	30	31.5	220.5	＋127.6
300	51	27.5	134.8	＋41.9
700(Current standard)	64	25.8	92.9	±0
1000	68	25.1	80.3	－12.6
1500	72	24.3	68.0	－24.9

A detailed analysis of SO_2 discharge standard and abatement cost shows that SO_2 is identical with COD in that the low discharge standard does not necessarily result in an abatement saving which can make up the environmental loss from SO_2 discharge increase. On the contrary, the increase of SO_2 discharge standard does not mean an outstanding cost for single enterprise, but for all the enterprises it should be a great input. Therefore the current SO_2 discharge standard is suitable. Under the current discharge standard, the enterprise SO_2 compliance rate is 64%. But when the standard is increased to 300mg/m^3, the compliance rate will be 51%. The additional cost for the non-compliance enterprises to meet with the standard is 17000 yuan and not obvious. Therefore, the current SO_2 discharge standard can be stricter and may be increased from 700 mg/m^3 to 500mg/m^3 under the current situations in China.

4.3 Prior investment pollution industries

Each pollutant has its corresponding main pollution industries. Each main industry has different process and different difficulty and thus has different abatement cost. For the decision-makers, the prior investment pollution industries are usually required to determine, so as to achieve best social pollution control effects.

COD prior abatement industries

The discharge, reduction rate and the related direct treatment cost and marginal abatement cost of COD main pollution industries in 1995 are given in Table 12[18]。 In this table the abatement cost for papermaking industry does not include that of Silvola recovery. According to the estimate for papermaking wastewater treatment in the Huaihe River basin, the Silvola recovery process cost is 1495 yuan/t COD. The cost including that for Silvola recovery is in the parentheses in the table. But we can not obtain COD MAC of papermaking industry including Silvola recovery.

Table 12 Discharge and Abatement Situation of Main COD Pollution Industries

Industry	Discharge in 1995 (10000t)	Reduction rate(%)	Abatement cost (yuan/t)	MAC (yuan/t)
Papermaking	321.4	40	686.4(2181.4)	70.8
Food products	53.9	75	1248.2	494.1
Chemical	71.2	44	1810.0	211.7
Medical	26.9	73	2610.3	925.0
Drink products	107.8	62	528.5	121.0

[18] In which the discharge is statistical data on county-and-upper enterprises in 1995, and the reduction rate is based on database developed by CRAES.

Textile	25.2	67	2624.3	730.4
Ferrous-metal metallurgical & calender	19.1	20	1790.9	72.1

Prior abatement industries can not be determined only by pollutant abatement cost and MAC. The pollutant discharge and reduction situations should also be considered. Put ferrous-metal metallurgical and calender process industry as an example, it has small COD discharge and small reduction potential despite that it has less abatement cost. So all the above factors should be comprehensively considered in the determination of prior pollution industries.

The screening of prior COD abatement industries is close with the abatement target and the abatement investment. It will be different under different abatement targets and policy aims. This can be described in three cases: i) all the industries having the same increased percentage of COD reduction rate; ii) all the industries having the same increase of reduction amount; and iii) all the industries having the same fixed investment for abating pollution. Table 13 gives the order of the COD prior investment industries which varies with different policy orientation.

Table 13 COD Prior Investment Industries Ordering

Industry	Policy target		
	Increase of the same reduction rate	Increase of the same reduction amount	The same investment intensity
Papermaking	5	7	5
Food products	4	4	2
Chemical	3	3	4
Medical	7	6	6
Drink products	2	2	1
Textile	6	5	7
Ferrous-metal metallurgical & calender	1	1	3

Comprehensively considering the COD prior investment industries ordering, it can be seen that the most prior industry is ferrous-metal metallurgical and calender industry, with drink products industry as the second. The last three industries are medical industry, textile industry and papermaking industry[19]. The chemical industry and food products industry are among the middle of the ordering.

SO_2 prior abatement industries

The discharge, reduction rate and the related direct treatment cost and marginal abatement cost of SO_2 main pollution industries in 1995 are given in Table 14[20].

[19] The less priority of papermaking industry is mainly due to the exclusion of silvola recovery cost from the total in most samplings.
[20] In which the discharge is statistical data on county-and-upper enterprises in 1995, and the reduction rate is based on CEMC database.

Table 14 Discharge and Abatement Situation of Main SO_2 Pollution Industries

Industry	Discharge in 1995 (10000t)	Reduction rate(%)	Abatement cost (yuan/t)	MAC (yuan/t)
Electricity, steam and hot-water production and supply	717.8	22	3348	67
Building materials and non-metal mineral products	123.2	10	5039	479
Chemical	118.0	75	15782	3004
Ferrous-metal metallurgical & calender	84.0	16	54507	867
Non-ferrous-metal metallurgical & calender	61.3	59	2242	218
Food products	18.4	58	6171	576

Like the analysis of COD prior investment industries, we assume three policy targets under which the prior SO_2 abatement industries should be somewhat different from the former. Table 15 gives the ordering of prior SO_2 investment industries under the three cases.

Table 15 SO_2 Prior Investment Industries Ordering

Industry	Policy target		
	Increase of the same reduction rate	Increase of the same reduction amount	The same investment intensity
Electricity, steam and hot-water production and supply	1	1	2
Building materials and non-metal mineral products	3	3	3
Chemical	6	5	5
Ferrous-metal metallurgical & calender	5	4	6
Non-ferrous-metal metallurgical & calender	2	2	1
Food products	4	6	4

Comprehensively considering the SO_2 prior investment industries ordering, it can be seen that the most prior industry is electricity, steam and hot- water production and supply industry, with Non-ferrous-metal metallurgical and calender industry as the second. The last two industries are chemical industry and food products industry. The building materials industry, ferrous-metal metallurgical and calender industry are among the middle of the ordering.

4.4 Pollution control effects of different investment intensity

The pollution reduction is closely related to investment intensity, and different investment intensities will result in different control effects. According to the statistics on the databases of CEMC and CRAES, the average COD abatement investment cost is about 3000yuan/t (in 1995 price), and average SO_2 abatement initial investment is 3700yuan/t (in 1995 price).

In order to illustrate pollution reduction effects under different investment intensities, we assume that the investment for COD and SO_2 abatement is respectively 0.1%, 0.3% and 0.7% of the year's total industrial output value in each year starting from 1996. The growth rate of total industrial output value is assumed as 12% before 2000 and 9% after 2000. The calculation result is shown in Figure 13, in which the reduction refers to accumulation value starting from 1996.

From Figure 13, it can be seen that the different investment intensities play obviously different pollution reduction. With the increase of investment intensity, the pollutant reduction capability increases obviously. For COD as an example, if 0.1% total industrial output value is invested in COD reduction each year from 1996, the accumulative reduction scale will be 21.79 million t until 2000 and 111.19 million t until 2010. The intensity of investment is thus directly related with pollutant reduction capability and some amount of investment should be guaranteed so as to control effectively the pollutant discharge.

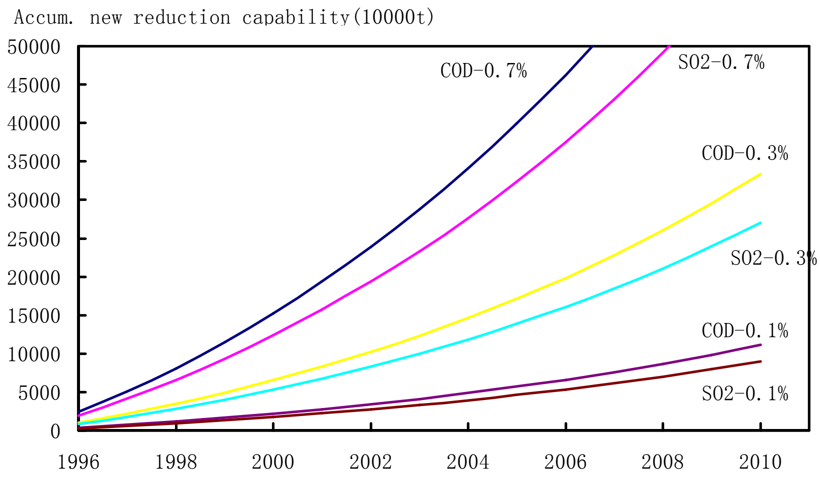

Figure 13 New COD and SO_2 Reduction Capability under Different Investment Intensities

5.0 Conclusions

- There is no great difference of pollutant discharge impacts among different industrial growth rates. Although from the viewpoint of environmental protection the low industrial growth rate is favorable to pollution control, the high growth rate is not necessarily a bad choice. It is thus concluded that, so long as the industrial structure is reasonable and the technical advancement and cleaner production is promoted, even the high growth is feasible.

- Either technical advancement or industrial structure adjustment plays very obvious roles in SO_2 discharge reduction. However the impact of technical advancement on SO_2 discharge is relatively greater than that of industrial structure adjustment. Therefore depending on technical advancement and developing the tertiary industry is an important policy measure. This is not true for COD. But as long as the current central control policy is continued to implement, the structure adjustment of increasing tertiary industry proportion should also be favorable to COD discharge reduction.

- It will be favorable to alleviation of the rapid growth trend of industrial pollution to reasonably control the industrial sectors with obvious pollution intensity and great pollution load, e.g. metallurgical, chemical, non-ferrous metal, electric power and building materials industries. However only to depend on industrial structure adjustment can not completely realize the country's pollutant total quantity control objective in 2000. A reasonable choice is to analyze the environmental impacts of various industrial policy schemes to determine an environmental-sound industry policy, when formulating the State industry policy.

- The larger the enterprise scale, the less its pollution discharge intensity. So, from the viewpoint of decreasing industrial pollution discharge intensity, the increase of enterprise scales is a *win-win* policy for both pollution reduction and economic efficiency. Therefore the scaled operation of enterprises should be positively promoted.

- The enterprise ownership reform will not only reduce its pollutant MAC but also decrease its pollution discharge intensity. The ownership reform of promoting private enterprises is also a *win-win* policy for both pollution reduction and economic efficiency.

- As the main pollution industries of COD and SO_2, the papermaking industry and electric power industry are both sensitive to the increase of EPLI or pollution charge rate. It shows that pollution charge is one good instrument for controlling industrial pollution.

- In order to realize the environmental protection objective in 2000 and improve the environmental quality, the EPLIs of four pollutants will be double for every five years on the basis of 1995. The EPLIs for COD and SO_2 are shown in the following table:

Pollutant	2000		2005		2010	
	EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)	EPLI (yuan/kg)	Discharge (10000t)

COD	0.14	1600	0.27	1440	0.7	1018
SO_2	0.07	2200	0.16	1980	0.33	1760

- The abating cost for COD and TSS from all the China's existing county-and-upper pollution sources to meet with the current Class II wastewater discharge standard is 20.16 billion yuan. The abating cost for dust and SO_2 to meet with the current air pollutant discharge standard is 36.34 billion yuan. The total abating cost is 56.5 billion yuan, accounting for 0.84% GNP of the year 1996.

- The Class II COD discharge standard is a suitable one and could not be looser under current status in China. If considering economic effectiveness, the SO_2 discharge standard can be increased from 700 mg/m^3 to 500mg/m^3 gradually.

- The order of prior COD abatement investment industries is: ferrous-metal metallurgical and calender, drink products, chemical, food products, papermaking, textile, and medical industries.

- The order of prior SO_2 abatement investment industries is: electric power, non-ferrous-metal metallurgical and calender, building materials, ferrous-metal metallurgical and calender, food products, and chemical industries.

- In order to effectively control the industrial pollution, capital investment should be guaranteed. For COD as an example, if 0.1% total industrial output value is invested in COD reduction each year from 1996, the accumulative reduction scale will be 21.79 million t until 2000 and 111.19 million t until 2010.

6.0 Acknowledgement

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