

Kitakyushu Initiative for a Clean Environment: Successful and Transferable Practices  
**Taiyuan (China): Win-win Practice of Integrating Environment and Economy (CP)**

Policy Research Centre for Environment and Economy<sup>1</sup>

**Target Area:** Cleaner production

**Time Period:** 1998-

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## **Introduction**

Taiyuan is an industrial city and a base of the energy and chemical industry in China. During the period of the traditional planned-economy system, the economic development of Taiyuan was characterized by non-intensive management and quantitative expansion. Consequently, high investment, high-energy consumption, and outdated production patterns have caused such heavy pollution that Taiyuan has been identified one of the most polluted cities in China. Additionally, massive exploitation has exhausted mineral resources in some parts of Taiyuan, although the area was once rich in mineral resources. Past experiences suggest that the traditional approach at end-of-pipe was not effectively resolve the industrial pollution problem, and outdated industrial production patterns could not address the resource problem. Against this background, the introduction of cleaner production in industrial enterprises becomes particular significant to Taiyuan, which can help alleviate heavy pollution while maintaining industrial growth.

## **1. Background: Reasons for implementation of CP in Taiyuan**

### **1.1 Brief introduction of Taiyuan**

Taiyuan, the capital of Shanxi province with a territory of 6,988 km<sup>2</sup> and population of approximately 2,600,000, is located in the Loess Plateau. There are six districts, one city and three counties under the Taiyuan municipal jurisdiction.

In 2000, the GDP of Taiyuan was RMB 34.75 billion, 7.8 percent higher than 1999. Among the GDP in the same year, the value added for agriculture, secondary and tertiary industries accounted for 4.3 percent (RMB1.5 billion) 48.7 percent (RMB16.91 billion), and 47 percent (RMB16.34 billion), respectively. The GDP per capita was RMB 11,418 (USD 1,387).

Taiyuan is a base of energy and chemical industries, as well as an important area of coal production in China. The production of raw coal reached 254,405,000 tons in 2000, which is 2.5 percent of the total raw coal production of China. Taiyuan is rich not only in the amount of coal-reserves but also in diversified types of coal resources such as coke, fat-coal, lean-coal and blind-coal. The industrial components of Taiyuan mainly consist of raw coal, coke, electricity, steel, chemical fertilizer and materials, which thereby produces the structural pollution pressure on Taiyuan environment.

### **1.2 Achievements and obstacles of environmental management in Taiyuan**

The unique characteristics in Taiyuan, such as a coal base, heavy-chemical-industry dominated structure, and quantitative expansion of economic growth, led to severe pollution in Taiyuan. This has led the Taiyuan Municipal Government to place environmental protection on an important agenda. Since the 1980s, the Government has placed more attention on urban environmental

protection and integrated environmental considerations into the master planning for city development and relevant programs for social and economic development. Since 1986, the government has invested RMB 1.6 billion in environmental pollution prevention and control, in addition to shutting down 2100 small-sized enterprises with backward technologies and production processes, as well as heavy pollution, and a 161.5km<sup>2</sup> area of dust control has been established. Significantly, the largest thermoelectric project in China, a power plant and central heating system, was established in Taiyuan. The centralized heating system of the plant covered 7 million m<sup>2</sup> so that when the 280 dispersed heating boilers in the urban areas were closed, it reduced 20 tons of coal consumption, 1400 tons of dust and 3900 tons of SO<sub>2</sub> emission each year. The percentage of household access to gas fuel is 85% at present. Two garbage disposal plants are now in place and treat 70.49% of municipal garbage. In addition, intensive actions to control pollution of ‘Mother river - Fen river’ has obtained periodical achievements.

Although Taiyuan has achieved certain progress by strengthening environmental management and control measures at end-of-pipe, environmental pollution problems cannot be resolved efficiently and have even become more severe in some aspects. Taiyuan is still listed as one of the most heavily polluted cities in China, due to the severity of petroleum substances, ammonia and hydroxybenzene in Fen-river, and a higher pollution index than the national standard. The Fen-river in Taiyuan has also become one of the fourteen most seriously polluted rivers in China.

In order to improve environmental protection and essentially resolve serious environmental pollution, Taiyuan must change its traditional patterns of industrial growth through innovating production technologies and reducing pollutants in the production process, and finally achieving win-win effectiveness where pollution is controlled while industries are booming. For these reasons, CP strategy becomes an inevitable choice for Taiyuan to protect the environment and pursue sustainable development.

## **2. Progress in implementing CP in Taiyuan**

CP can mitigate pollutant generation at the production source and processes. On the one hand, CP minimizes pollution through the use of cleaner energy and raw materials, introduction of cleaner production processes, and selection of techniques and equipment with low energy consumption, less pollution and high benefits. The outputs of CP shall also be cleaner products harmless to the health. On the other hand, the CP also minimizes pollution through reduction of resource consumption that is achieved by measures such as comprehensive utilization of resources, substitution of rare resources, and reuse and recycling of resources. In a word, CP implies a philosophy and strategy of integrating prevention with treatment in pollution control. Therefore, the implementation of CP in Taiyuan is of realistic and long-term strategic significance to fully resolving environmental pollution

problems.

For this reason, Taiyuan Municipal Government has paid much attention to both the implementation of CP and industrial pollution control. In 1998 and 1999, Taiyuan was designated as a demonstration city for CP in China by UNEP and CCICED<sup>2</sup> and a CP pilot city by SETC<sup>3</sup> and SEPA<sup>4</sup>. To formally initiate the implementation of CP, a Conference on Program CP Demonstration City was held in Taiyuan in March 18, 1999. In order to facilitate concrete actions of CP, the Municipal Government signed a science and technology cooperation agreement with TsingHua University, and an advisory group headed by Prof. Qian Yi, a famous environmental expert, was established, consisting of five academicians and four professors. After the investigation, the experts proposed Programs for Promotion of CP in Taiyuan. Prof. Qian Yi was invited to make a speech on CP for officials and citizens on local TV, which was broadcast for the purpose of raising social awareness and creating common ground for the implementation of CP. Moreover, the Municipal Government made a special decision on promotion of CP. While Taiyuan was making self-efforts in implementing CP, the Chinese central government and Shanxi provincial government as well as international organizations provided strong support to Taiyuan City. In 1998, for example, the State granted 5.56 billion RMB to Taiyuan for the construction of infrastructure, and most of the investment was used for environmental projects. Taiyuan was designed as a pilot city for both “21 Century Agenda” and cleaner energy by Shanxi province. The World Bank and the Asian Development Bank also have plans to finance environment and energy projects in Taiyuan.

With the supports of the national and provincial government, Taiyuan Municipal Government set up a leadership group of CP and formulated philosophies, which pay equal attention to economic development and environmental protection, integrate economic benefits with social benefits, and follow sustainable development strategy. In addition, the Municipality makes efforts in establishing relevant organizations and law/regulations, and creating a sound environment for introduction of CP.

On November 30, 1999, the Taiyuan City Regulation of CP was enacted. This regulation, the first of its kind for CP in China, played an important role in promotion of the implementation of CP. The Municipal Government issued several critical plans and related programs, such as the Medium and Long-term Plan for CP in 2001, the Implementation Scheme of CP in Taiyuan, and the Assessment System of CP in Taiyuan, etc. Moreover, the Municipality established a database of CP projects, and compiled special program of CP projects for business investment and international cooperation. In a word, a preliminary framework of policies for implementation of CP, including the local regulations, plans, implementation schemes and assessment system, has been established in Taiyuan.

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<sup>2</sup> China Council for International Cooperation on Environment and Development

<sup>3</sup> State Economy and Trade Committee

<sup>4</sup> State Environmental Protection Agency

In promotion of CP, the Municipal Government has emphasized the introduction of CP in the heavy polluted industries. Nine enterprises has been designated as pilot enterprises for implementation of CP projects, including Taiyuan Steel Corporation, Taiyuan Shitou Cement Limited Group Corporation, Taiyuan No.1 Thermal Power Plant, Taiyuan No.2 Thermal Power Plant, Taiyuan Chemical Group Corporation, Taiyuan Gas Corporation, QingXu Gas Corporation, Taiyuan Aluminum Corporation, and XinKai Spinning Group Corporation. It is predicted that these pilot projects would to a large extent improve the environment of Taiyuan. Besides the nine pilot enterprises, additional enterprises in Taiyuan plan to carry out CP stage by stage. At the same time, measures adopted by Taiyuan, such as adjustment of industry structure, acceleration of treatment of garbage and sewage, control of the automobile exhaust, and environmental education, will help to upgrade Taiyuan City in both environment and economic and social development.

Although the implementation of CP in Taiyuan is still in the initial stage and the whole picture of pollution in Taiyuan has not yet changed, pilot enterprises have achieved win-win benefits of mitigating pollution while promoting business. The Taiyuan Shuangta Aluminum Oxide Stock Limited Corporation, for example, implemented CP following the principle of promotion of production without increase of pollution, and minimized pollutants through reduction of resources consumption at sources and improvement of production processes. As a result, the Corporation has obtained evident benefits of both environmental and economic. The Taiyuan Boiler Group Corporation has achieved great economic benefits through adjustment of the quality management system and supply of low-pollution products of CP. The Taiyuan II Power Plant has produced high quality and various types of construction bricks through introduction of an automatic equipment and technologies of coal-dust product making from Germany, and thereby the Corporation become a paradigm of implementation of CP. Totally, application of CP becomes a new trend the industries prefer to follow in Taiyuan at present.

### **3. A CP case analysis on environmental and economic benefits: Taiyuan Group Chemical Plant (TGCP)**

#### **3.1 General situation of TGCP**

TGCP was founded in 1958. It produces chlor-alkali, phenol, chlorobenzene, polyvinyl chloride, cyclohexane, and hexane di-acid. Chlorobenzene, the main product of the plant, is very important for production of chlor-alkali, balance of chlorine and increase of business profits. It is also directly related to the use of the production capacity of the whole plant. In the past 40 years, the Plant supplied a great deal of chemical raw materials to the country, and made great contribution to the national economy. But the TGCP installed with very much outdated process and technologies of production at the levels of the 1950s and 1960s. As a result, efficiencies of material inputs and

energy in the production were so low that a part of resources and energy discharged to environment in pollutants. Both the concentration of COD in wastewater and the concentration of benzene in emission gas were much higher than the national emission/discharge standards. It once resulted in violent conflicts between the enterprise and public, and moreover, frequently occurrences of environmental disputes constituted a restriction to the development of the plant.

### 3.2 CP projects and plans

In order to change the situation of heavy pollution and its serious impact on normal order of production, the TGCP made a decision to introduce the CP in the mid-1990s. From the year of 1994, the TGCP identified its production processes with massive consumption of materials and energy and with heavy pollution, and then made a plan for technique transformation and introduction CP technologies step by step. In order to select concrete schemes for implementation of the CP, the TGCP conducted the CP audits for the production equipment of chlorobenzene.

The production of chlorobenzene is divided into several processes: material delivery, desiccation of benzene, chlorination, neutralization with water, rude distillation, rectification, packing, absorption of the emissions, and multiple-chloride. Through the CP audits, 12 substitution schemes were made for technique transformation of production of chlorobenzene, including 4 no-cost schemes, 2 low-costs schemes, 3 medium-cost schemes, 3 high-cost schemes (table1-1).

**Table 1-1 CP schemes for Chlorobenzene Production Process**

Schemes		Target processes for transformation and pollution problems	Improvement means
Type	Number		
No-cost	F <sub>1</sub>	Chloride emission gas cooler, poor cooling effect	Replace the parallel connection with series
	F <sub>2</sub>	Emission gas catcher, wastewater discharged directly	Reutilization of the wastewater
	F <sub>3</sub>	Benzene desiccation, wastewater discharged directly	Reutilization of the wastewater
	F <sub>4</sub>	Rude distillation cooler, emission gas discharged without treatment	Reutilization of the waste gas
Low-cost	F <sub>5</sub>	Chloride cooler renovation	Replace the horizontal cooler with vertical one
	F <sub>6</sub>	Alkali washing drainage renovation	Add a suit of chloride separator,
Medium-cost	F <sub>7</sub>	Water washing drainage renovation	Reapply washing water to absorb the chloride emission and produce HCl with water
	F <sub>8</sub>	Multiple chloride renovation	Increase the height and trays of the multiple-chloride separating tower
	F <sub>9</sub>	Process renovation	Renew the rude distillation and rectification heater
High-cost	F <sub>10</sub>	Emission gas transfer (including process renovation)	Adjust the industrial layout, replace two-phase with three-phase
	F <sub>11</sub>	Cooling water circulation utilization	Add a cooling tower with 400 tons/hr water
	F <sub>12</sub>	Production process renovation	Increase production ability

### 3.3 Annual economic and environmental benefits of implementing CP

For the production process of chlorobenzene, the TGCP got significantly economic and environmental benefits through carry-out of substitution schemes (table 1-2 and 1-3).

**Table 1-2 Annual Economic Benefits of Implementing CP (ten thousand RMB)**

Schemes		Investment	Income	Operation cost	Net income	Recovery period for investment (year)
F <sub>1</sub> - F <sub>4</sub> (no-cost)			84.90		84.90	
Low-cost	Chloride cooler renovation (F <sub>5</sub> )	3	26.6		26.6	0.11
	Alkali washing drainage renovation (F <sub>6</sub> )	6.3	60	1.75	58.25	0.11
Medium-cost	Water washing drainage renovation (F <sub>7</sub> )	14.7	50	10	40	0.37
	Multiple chloride renovation (F <sub>8</sub> )	30.7	4		4	7.7
	Process renovation (F <sub>9</sub> )	22.13	89		89	0.25
High-cost	Emission gas transfer (F <sub>10</sub> )	87.96	84.11		84.11	1.05
	Cooling water circulation utilization (F <sub>11</sub> )	87.7	162.72	32.3	130.42	0.67
Total		252.49	561.33	44.05	517.28	0.49

From the table 1-2, the annual investments in the implementation of CP in the TGCP were 25,249,000 RMB, but the annual net incomes were as high as 51,728,000 RMB, and the recovery period of the investments was only a half-year.

From the table 1-3, through the introduction of CP, the wastewater was reduced by 349,000 tons; the amount of HCl from the wastewater and emission gas, by 906.85 and 395.72 tons, respectively; the chlorobenzene, by 69.01 tons; and the chlorine, by 3.22 tons. Totally, the pollution problem caused by the process of chlorobenzene production was resolved.

**Table 1-3 The Annual Environmental Benefits of the Implementation of CP**

Pollutants		The reduction of pollutants (ton)
Wastewater		349000
	HCl	900
	Benzene	47.94
	Chlorobenzene	43.41
Emission gas		
	HCl	6.85
	Chlorine	3.22
	Benzene	347.76
	Chlorobenzene	25.6

### **3.4 Successful experiences in implementing CP**

Three approaches and measures ensure the successful implementation of CP in TGCP: self-effort to overcome the obstacles in funds and technique, reorganization of business environmental management, and enhancement of managerial systems.

#### ***(1) Self-effort to overcome obstacles in funds and technologies***

Generally, shortages of funds and technologies constitute common and critical obstacles in implementation of CP. To overcome the obstacles, the TGCP relied on self-efforts, instead of doing nothing else but passively waiting for the coming of external supports or the self-financial capacity getting available. Concretely, the TGCP adopted the following approaches to resolve financial and technical difficulties. First, the TGCP introduced the CP schemes step by step from the easy to the difficult, namely, from the no-cost and low-cost schemes to medium-cost and high-cost schemes. In this way, the revenues from the no-cost and low-cost schemes can be used to invest in the medium and high cost schemes, so that the whole CP program could be fully implemented in a certain period. Second, the TGCP took advantage of its own human resources to complete technological transformation, simple equipment manufacture, and in particular installation of equipment. And also the introduction of CP schemes might be integrated with the general equipment maintenance and general technological transformation for production process that conducted by the enterprise regularly. These two approaches were done in order to save the implementation costs of CP projects. Third, for those technical difficulties the TGCP couldn't resolve in the implementation of CP schemes, the TGCP got the solutions through dispatching its technicians to learn from the relevant industries.

#### ***(2) Reorganization of internal business environmental management***

Under the traditional strategies for business environmental management which focus on pollution control at the end-of-pipe, the TGCP installed the Environmental Protection Division responsible for monitoring and checking whether the concentrations of pollutant emissions/discharges meet the national or local relevant standards, or not. But this regime ignored the raw material consumption and the pollutant generation in the process of production. In other words, it separated the linkage between pollution control and production. Fortunately, the experiences in implementation of the CP projects changed the philosophies of the TGCP in internal environmental management. The original division was reorganized as the Division of Production and Environment. The mission of the Division is not only to abate pollutants at the end-of-pipe but also to minimize pollutant generation in the production process. It has fully incorporate pollution control into process improvement. Consequently, pollution control and production management in the TGCP become mutually dependent and promotion.

### ***(3) Enhancement of business management***

The CP audits identified several problems such as material loss in production process through various ways. To resolve the problem, the TGCP formulated and modified rules and managerial systems for equipment maintenance, increase of operation ratio of equipment, periodical check of equipment, and quota-setting for material consumption. At the same time, the TGCP linked salaries and bonuses of workers with their environmental and production performances. In other words, workers who comply with the rules and managerial systems can get higher salaries and bonuses; otherwise they would be fined. This system has been monthly reviewed. The practices in the TGCP suggest that the combination of administrative system and economic incentive could help enterprises consolidate the results of the implementation of CP.

## **4. Strategic implications of the implementation of CP in Taiyuan**

The CP aims at energy conservation and reduction of resource consumption as well as minimization of pollution. The goals are achieved through application of pollution control measures at the source and in the process of production, on the basis of technological and managerial improvements. As a result, the CP can eliminate or mitigate the impacts of industrial production on environment and human health, and obtain the win-win effects of controlling industrial pollution while promoting business profits. In this sense, the CP has a good prospect for applications in developing countries.

To overcome the obstacles of financial and technological shortages to the implementation of CP, industries in developing countries may follow the approaches from the easy to the difficult projects. In so doing, the industries can use the revenues obtained from the easy project to invest in the difficult projects. At the same time, cooperation between countries and between industries is very important to attack the technical difficulties in the implementation of CP.

Introduction of the CP may provide an opportunity to reorganize internal business environmental management and strengthen relevant managerial measures. The purposes of reorganization are to integrate pollution control actions with production activities in enterprises and to further form a mutually dependent and promotional relationship between them.

In promotion of the CP, the relevant laws/regulations, preferential policies, and plans shall be first in place. In this regard, the central and local governments have non-substitutable responsibilities, and also governments need provide financial supports or incentives and technical services for industries in implementation of the CP, in particular at the initial stage of popularization of the CP.