Project Report on the Reduction of Mercury Use and Emission in Carbide PVC Production

Ministry of Environmental Protection

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Contents

Introduction

According to Small-Scale Funding Agreement-“Mercury Use in Vinyl Chloride Monomer Production” signed by United Nations Environment Programme (UNEP) and Ministry of Environmental Protection (MEP) in 2008, this report includes two main parts. The first part is a description of mercury use and reduction in carbide PVC industry in China, and the second is an analysis of policy demand for mercury environmental management of PVC industry. Proposed mercury reduction actions for China’s acetylene PVC industry are drafted in a separate report.

The basic data and information contained in the report come mainly from a series of work carried out during the implementation of the project, including the survey on industry, investigation on industry management, and "workshop on mercury reduction in Carbide PVC Production" in June 2009, etc. Contents of the report have been reviewed by experts of the industry to ensure that the information in the report is accurate and reliable.

Part 1 Mercury use and reduction in carbide PVC industry

1 Current status and development trend of PVC industry

1.1 General situation of the industry

The chlor-alkali industry is a basic raw material industry and plays a key role in the economic growth of China. The Chinese Government has always taken the output of major chlor-alkali products as an important indicator for the national economic statistics assessing the performance of the national economy. PVC resin is a key product of the chlor-alkali industry with wide use, huge demand, and rapid development. At present, almost all foreign countries apply the ethylene process to produce PVC resin. Both the carbide process and ethylene process are employed in China.

The carbide method is a PVC resin manufacturing technology with carbide as main raw material and mercury chloride as a catalyst. The development of this technology has drawn great attention of the Chinese government due to environmental problems related to the use of mercury, treatment of carbide slag in the process, and the increasing international concern about mercury pollution. Many administrative and control policies have been promulgated and implemented over the past few years, trying to gradually guide the industry to develop in a more sustainable, sound, and stable manner.

1.2 Current status and development trend of PVC supply and demand

1.2.1 PVC production capacity, output, import and export

The industry survey data shows that there are now more than 100 PVC manufacturers in China with average capacity at 150,000 t. In 2007, the total PVC output of China reached 9.72 million t with total capacity of 14.59 million t. In 2008, the output went down to 8.82 million t with capacity going up at 15.81 million t. With PVC capacity and output exceeding that of the United States, China is now the biggest PVC manufacturer in the world.

The figure 1 presents PVC production capacity and output of China over the past few years. It can be seen that PVC capacity and output of China was on steady rise from 2001 to 2007 but declined in output in 2008 due to the international financial crisis, while the capacity still went up.

Figure 1 PVC production capacity and output in China during 2001-2008

(Data from China Chlor-Alkali Industry Association)

In the past, China's PVC supply depended on import. The domestic PVC industry has been under rapid development since 2003 with a significant increase in exports. In 2006, PVC export from China reached 460,000 t, and PVC export has maintained a relatively fast growth since then while the import amount shows gradual decline year by year. Table 1 shows PVC import and export in China over the past 5 years.

Table 1 PVC import and export in China during 2004-2008 * (Unit: 10,000 t)

Year	2004	2005	2006	2007	2008
Import	162.8	130.7	114.7	110.1	79.75
Export	1.7	11.9	46	71.17	59.96

***Data from China Chlor-Alkali Industry Association**

1.2.2 Status of PVC production process

PVC enterprises use VCM to synthesize PVC by four methods, i.e. suspension, emulsion, bulk and solution polymerization. The suspension polymerization process has been the key method for PVC manufacturing due to its mature production process, simple operation, low cost, good economic benefits and wide application field. At present, over 80% of PVC output in China uses the suspension polymerization process. Though there are different PVC polymerization processes, PVC production processes are usually identified by the raw material route of VCM production. They mainly include the following:

(1) Using the carbide acetylene method to produce VCM, then synthesize it into PVC;

(2) Using petroleum ethylene as raw material to produce VCM by the ethylene oxychlorination method, then synthesize it into PVC;

(3) Using the ethane dichloride (EDC) decomposition raw material route to produce VCM, then synthesize it into PVC;

(4) Using imported VCM to synthesize PVC;

(5) Using the natural gas partial oxidization method to produce acetylene that generates VCM, then synthesize in into PVC.

At present, almost all foreign PVC manufacturers adopt the ethylene process, while two of such PVC production processes exist in China.

Based on acetylene process and ethylene process, there are the following three raw material routes for PVC production in China, i.e. ethylene oxychlorination, carbide method and import VCM and EDC method. According to the industry survey data, in 2005, PVC output of the carbide route took up about 70% of the total output, PVC output employing the ethylene oxychlorination route accounted for about 14% and the output applying imported VCM and EDC route accounted for 16%. In 2007, PVC output employing the carbide route took up about 72% of the total, PVC output employing the ethylene oxychlorination route accounted for about 13% and that using imported VCM and EDC accounted for about 15%. In 2008, PVC output employing the carbide route took up about 70%, and that applying the other two routes accounted for about 30%.

1.2.3 Necessity of carbide acetylene route

The carbide acetylene process to produce PVC would not be eliminated in a short time due to the energy mix and resource structure of China. It is the PVC resin production technology with Chinese characteristics that meets China's specific conditions.

(1) The resource structure of China— rich in coal and mineral resources but poor in oil— leads to the long-term existence of the carbide process for PVC production. As carbide production requires huge amounts of coal, China, rich in coal, has great potential in the production of carbide and provides a reliable supply of raw materials for PVC production by the carbide method. In the period of continuous rise of petroleum price in the world market, PVC production by the ethylene process is under constraint. Meanwhile, manufacturers employing the carbide process shoulder the heavy task of meeting the PVC market demand in China and play an important role in ensuring healthy and steady development of the industry. Although current petroleum price fluctuations due to the international financial crisis makes PVC manufacturers applying the carbide process face temporary difficulties, domestic manufacturers will eventually show their development advantage when the international oil price is rationalized and the domestic coal market matures. Therefore, the carbide PVC production process meets China's specific conditions

and domestic development requirement, and has the room for development in China.

(2) Ethylene technology in China has reached an internationally advanced level, but the production capacity is relatively weak. Domestic supply of the raw materials is insufficient, which to a large extent depends upon import, and thus impedes the development of ethylene PVC production in China. We need increased PVC productivity by the carbide process to make up for the deficiency of ethylene process in order to ensure long-term, stable and sustainable development of PVC industry in China.

(3) With several decades of history, PVC production by the carbide process in China has developed into a PVC manufacturing technology with Chinese characteristics, forming a set of well-established carbide-process production technologies. China responded to the development of clean production technologies over the past few years and the application of these technologies to a large extent raises the overall technological level of PVC production by the carbide process. Current PVC production technology by the carbide process is able to meet the existing emission standards, which can gradually evolve into environment-friendly or green technology.

1.3 PVC production process by acetylene hydrochlorination

At present, there is only one PVC production process in China using carbide as raw materials. That is, firstly using carbide to produce acetylene gas, then, under the catalysis of mercury catalyst, using acetylene gas and HCl react to generate VCM which is then polymerized into PVC in polymerizer. The figure 2 shows the process.

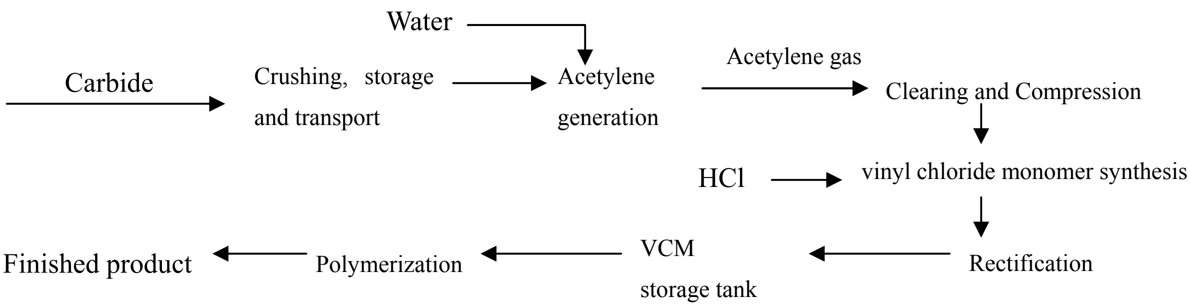


Figure 2 PVC process flowchart by acetylene process

1.3.1 Acetylene preparation

The first thing to produce VCM in the carbide acetylene hydrochlorination process is to prepare acetylene, which together with $Ca(OH)_2$ are the products of chemical reaction between carbide and water. There are two kinds of acetylene manufacturing methods in China based on different method to treat $Ca(OH)_2$: one is the generation of calcium hydroxide powder, also called the dry method; the other is employing water to carry $Ca(OH)_2$ forming slurry, also called the wet method. At present, Chinese manufacturers mainly adopt the wet method. The use of the dry method which was developed in 2006 has been promoted in the PVC industry due to the ease of use of the dry powder.

1.3.2 $HgCl_2$ catalyst production

There are two conventional processes – the immersion absorption method (wet method) and the gas-phase absorption method (dry method) - for the production of mercury catalyst to be used in acetylene VCM production. The immersion absorption method was introduced from overseas, while gas-phase absorption method is China's independent innovative process developed in 1980s to replace the immersion absorption process. In the mid 1990s, with the development of the compound mercury catalyst which is of relatively low concentration of $HgCl_2$, the relevant PVC manufacturers had to employ the immersion absorption process again due to the fact that the gas-phase absorption method was not suitable for the production of the compound mercury catalyst. With significant time for improvement, this process has become more scientifically sound with a higher degree of automation.

The industrial water achieves closed circulation in the improved wet production process without any discharge of waste water. The fine and powder mercury catalyst generated from production that does not meet size requirement are collected to recover the mercury by pyrometallurgical process and not discharged. After going through the absorption tower to remove mercury and dust by activated carbon, the waste gas enters an alkaline fluid washing tower for further removal of mercury and dust removal. After neutralization by HCl and sedimentation, the waste water from the washing tower is reused in the immersion absorption process in the production of mercury catalyst.

1.3.3 PVC production

After crushing, carbide reacts with water in an acetylene generator to produce acetylene gas. After such processes as washing, cooling, cleaning and drying, the generated acetylene gas is sent to a vinyl chloride synthesis converter and mixed with hydrogen chloride in the converter which generates vinyl chloride monomer under the catalysis of mercury. After purification, compression and rectification, the vinyl chloride is sent to a PVC manufacturing device. In the polymerizer, suspension polymerization technology is employed to manufacture PVC. After such processes as centrifugalizing, drying and packaging, the PVC is made into final product for sale.

During the production process mercury containing wastes such as waste mercury catalyst from VCM converter, waste active carbon from mercury remover, mercury-containing sludge from waste water treatment facilities, and mercury-catalyst packaging bags are transported to a certified enterprise to recycle and reuse. The alkali washing water, mercury-containing waste acid, and rainwater in the plant is piped to a mercury-containing waste water treatment plant for treatment. The treated waste water which has met the discharge standard is sent to GE zero discharge facilities for re-treatment, and then piped into circulation water system for reuse.

1.4 Current status and development trend of PVC roduction by acetylene hydrochlorization

According to the industry survey data, in 2008, there were 89 PVC manufacturers in China applying the acetylene hydrochlorination process with a total capacity of 11.605 million t and total output of 6.20 million t. The production capacity distribution is shown in the Table 2.

Table 2 Amount of PVC manufacturers using acetylene process and their capacity distribution in China (2008)

Capacity range (10,000 t)	Amount of enterprises	Production capacity (10,000 t)	Percent (%)
≥ 20	20	609	52.2
≥10 ~ < 20	31	387	33.2
≥5 ~ <10	20	123	10.5
<5	18	47.5	4.1
Total	89	1160.5	100

The above table shows that in 2008 the total capacity of acetylene PVC manufacturers in China with capacity over 100,000 t each took up about 85.4% of the total, while the aggregated capacity of PVC manufacturers with capacity less than 100,000 t accounted for 14.6%. With tighter national control on the production scale of new or reformed (expansion) projects, it is expected that the proportion of large-sized enterprises will increase.

The development of PVC production by the ethylene process is under a large constraint due to such factors as short supply of ethylene, VCM and EDC, and high investment in production facilities with the oxychlorination process. In contrast, PVC production by the acetylene process becomes a hot spot for the investment in the PVC industry due to such advantages as small investment, high availability of domestic made equipment, comparatively simple technical process, and a big profit margin. According to the industrial forecast, it is expected that most new or expansion projects of PVC production facilities in China will still employ carbide as raw materials in the next few years and acetylene hydrochlorination process will still be the main process for PVC production.

2 Current status and development trend of mercury reduction

2.1 Status quo of mercury consumption and emissions

PVC production by acetylene hydrochlorination is the process with mercury chloride serving as the catalyst. Theoretically, the process does not consume mercury. However, mercury catalyst will lose its function after a certain operational period due to the concentration decline of mercury chloride in the catalyst resulting from evaporation loss of mercuric chloride during the production process.

At present, the mercuric chloride concentration of the mercury catalyst used by most enterprises usually is around 12.5%. When the mercuric chloride concentration drops to around 4.5%, the mercury catalyst tends to lose its function and be replaced by new ones. It is estimated that the average mercury catalyst consumption per ton PVC in China is about 1.0~1.4kg. Based on the above-mentioned parameters and 2008 acetylene PVC output of about 6.2 million tons, the annual use of mercury is about 574~803t of which, about 206~289 t mercury remains in the waste catalyst and the rest is in the activated carbon, waste acid, emissions to the environment and other waste. Since 2008, PVC companies, affected by the financial crisis, have decreased their PVC production to certain extent. But PVC production will increase with the recovery of the economy and as such mercury use will increase too.

PVC industry is the number one consumer of mercury in China. Although relevant enterprises have taken effective prevention and control measures in collecting and treating mercury-containing wastes such as applying activated carbon to absorb evaporated mercury, transporting waste mercury catalyst to an enterprise with a license to recycle such waste, concentrated treatment of mercury-containing waste acid and recycling and reuse of mercury-containing waste water, it is estimated that small amounts of mercury will be discharged into the environment during the production process. Therefore, how to effectively address the problem of huge consumption of mercury and mercury pollution of the PVC industry is a grave environmental challenge facing the acetylene PVC manufacturers.

2.2 Mercury reduction measures

Reducing the use and release of mercury, and minimizing the generation and emission of mercury-containing waste is the basic idea for the prevention and control of mercury pollution in the PVC industry by acetylene process. At present, the industry applies such technologies and measures as development and application of low-mercury catalyst, technological reform to prevent the mercuric chloride evaporation, prevention of catalyst poisoning, and delaying carbon deposition to reduce the use and consumption of mercury. With the application of such measures as HCl desorption and reuse of waste water, the generation and discharge of mercury-containing waste is minimized.

2.2.1 Development and application of low-mercury catalyst

Mercury chloride concentration of low-mercury catalyst is usually about 6%, half of the conventional mercury catalyst (mercury concentration at 12.5%). Low-mercury catalyst is a new type of catalyst employing special technology to fix mercuric chloride in effective pores of activated carbon, which greatly raises the activity of catalyst and reduces mercury sublimation rate.

With HCl, mercury chloride, and activated carbon as main raw materials, low-mercury catalyst is manufactured by a special process. After unique HCl and $HgCl_2$ soaking and drying treatment, the catalyst will be further treated by supporting ingredients, anti-tackiness agent, stabilizer and anti-toxicity reagent respectively. The mercury catalyst thus manufactured has high porosity. Mercuric chloride occupies the absorption center with strong activated carbon and forms the reaction activity center. It overcomes such shortcomings as too high activity in early period of VCM synthesis and difficulties in controlling the reaction temperature. This new catalyst is of relatively long service life, higher activity, and better selectivity. New and environment-friendly low-mercury catalyst is able to get similar or better catalyzing effects compared with that of conventional high-mercury catalyst.

The manufacturing process of the mercury catalyst employs whole-process closed piping without any leakage of gas and water. The broken mercury catalyst is fully recycled and reused. The coal cinder is transported to a cement manufacturer as raw material. The water, gas, and slag generated in the production process will not be discharged to the ambient environment.

The application of low-mercury catalyst began in 2006 in China's PVC industry. Up to 2008 the PVC capacity using low-mercury catalyst has reached about 1,230,000 tons. The results show no decline of activity conversion rate and service life of the mercury catalyst but significant drop of mercury sublimation, which greatly reduces the use and consumption of mercury as well as the difficulty of follow-up pollution treatment. Therefore, in terms of its product function and application cost, the low mercury catalyst has been considered by the PVC industry an effective means to reduce mercury consumption in China's PVC industry and is being promoted.

2.2.2 Development and application of new type VCM converter

(1) Technical background

The mechanism of employing the acetylene process to produce VCM is to let the pre-heated mixture of HCl and acetylene flow into a reactor to generate vinyl chloride monomer (VCM) under the catalysis of the mercury catalyst at a temperature of 100～180 degrees. Traditionally, VCM is produced by a fixed-bed converter. The fixed-bed converter occupies a big area and has difficulty in removing reaction heat. It is therefore easy to cause excessive heat in part of the converter (hotspots). The reaction heat is neither conducive to mercury catalyst, nor to the improvement of capacity of individual equipment. However, the newly developed fluidized bed VCM converter is smooth in operation and able to control the temperature at different bed layers, thus further raising VCM conversion rate, reducing mercury catalyst sublimation, decreasing equipment investment and catalyst consumption, and dramatically improving the production capacity.

(2) Process flow

In the fluidized bed VCM synthesizing process, the pre-heated mixture of dry HCl gas and acetylene gas flows into the fluidized bed through the controller at the bottom of fluidized bed and fluidize the catalyst, and conduct addition reaction at appropriate temperature.

When the intake gas flow reaches a certain speed, in-bed gas flow speed will go up. Some catalyst will be carried by the air flow and accumulate onto the upper gas distribution broad, and return to the fluidized bed through overflow tube, and finally develop a balanced accumulation amount. Under controlled temperature conditions, it facilitates the chemical reaction of the gas in fluidized bed. During the operation process, a small part of catalyst will be carried out of the bed by air flow. This part of the catalyst will be returned to the fluidized bed through an air-solid separation device. The figure 3 presents the process flow.

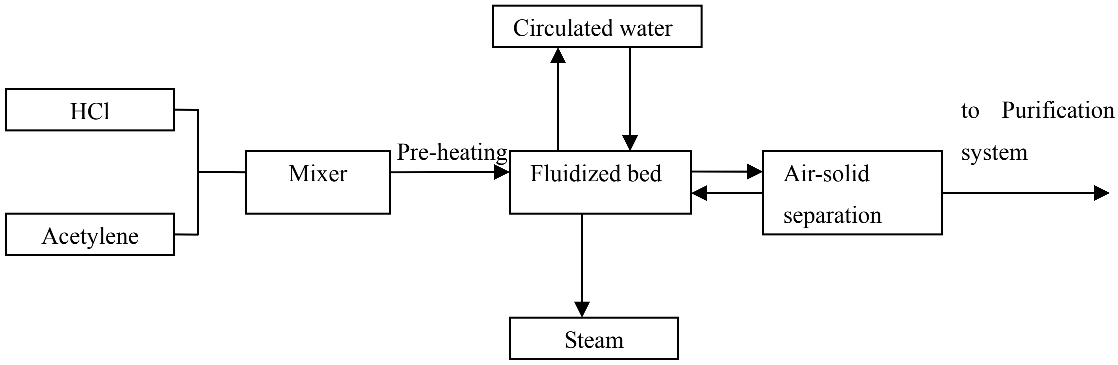


Figure 3 Flow chart of fluidized bed VCM production process

The new type of VCM converter with multi-layer fluidized bed can keep a constant flow rate of the mixed gases of HCl and acetylene gas. The acetylene conversion rate can be as high as over 99%. It can add or unload catalyst under airtight conditions, reducing direct loss of catalyst and environmental pollution. Because the technology and process themselves achieve emission reduction, the pollution caused by sublimation of mercury catalyst during the production process is significantly reduced.

At present, this technology has been employed by some enterprises in China in the production and is under continuous improvement. Some enterprises will finish pilot testing and begin pre-production testing in September 2009. It is expected that they will enter trial-production stage in 2010. Once mature, the application of this technology will be extended to other appropriate enterprises.

2.2.3 Development and application of mercury-free catalyst

The development of a mercury-free catalyst to replace mercury chloride catalyst can address the mercury pollution problem at the source. At present, there are many patent reports in the world. For example an unauthorized Japanese patent describes acetylene fixed bed hydrochlorination under catalysis of gaseous catalyzing. The catalyst in use is manufactured by depositing rare metal chloride onto activated carbon. However, there is no report on its industrial application. An American patent also describes a method synthesizing vinyl chloride by the reaction between acetylene and HCl. The catalyst in this process is dissolving palladium compound into aliphatic or heterocyclic amine organic solvent at the reaction temperature higher than room temperature. Another American patent introduces the preparation method for non-mercury catalyst system and the utilization of hydrochlorination that employs acetylene to produce vinyl chloride in such system. Systematic research finds good acetylene conversion rate in the non-mercury catalyst process but with relatively fast loss of active ingredients.

In addition, during the Workshop on Mercury Reduction in Carbide PVC Production in June 2009 in Beijing, Aker Solutions and Johnson Matthey presented their latest research and development on new mercury-free catalyst, but it is still in laboratory testing phase. The pilot test/demonstration test is to be conducted in the next stage.

Currently, China's mercury-free catalyst technology is still in the R&D stage. There is no relevant research reports and corporate trial. As a mercury-free alternative technology, it is the direction of China's PVC industry.

2.2.4 Application of mercury emission reduction measures

As stated above, theoretically, PVC production by the acetylene process does not consume mercury. The mercury loss is due to sublimation of mercuric chloride during the production process. Based on the characteristics of processes employed in China, the destinations of the lost mercury may be the following: absorbed by activated carbon in mercury remover, waste acid in water-cleaning system, mercury-containing effluent resulting from catalyst replacement operation, catalyst poisoning, and so on.

(1) Absorption by activated carbon in mercury remover

Mercury remover is the main mercury removing equipment commonly used in acetylene PVC production process. Activated carbon is employed to absorb sublimated mercury. In addition, some mercury-containing white solid substances may be cleaned at locations such as the end plate of pipes and mercury remover during the overhaul period. PVC manufacturers usually transport it together with waste activated carbon in mercury remover and waste catalyst to a certified enterprise for recycling and treatment.

(2) Waste acid in water washing system

After removing most mercury by mercury remover, primary VCM gas enters deacidification systems including the foaming and washing towers to form mercury-containing HCl (waste acid). After HCL desorption, most mercury-containing HCl enters the foaming tower for recycling use. Some HCl neutralizes with waste fluid from the alkali washing tower.

(3) Mercury-containing effluent resulting from catalyst replacement operation

The catalyst in the converter should be replaced after some period due to reduction of activity. The catalyst in the tube array of the converter will be drawn out into the storage tank due to a pressure difference between the catalyst storage tank and the converter, produced by the water jet vacuum pump. The dust resulting from the replacing process is removed by spraying water in the dust remover, thus forming mercury-containing effluent. At present, industrial practices include recycling and reuse of mercury-containing effluent and collection of mercury-containing sludge and waste catalyst together for treatment and disposal.

The replacing method for the activated carbon in the mercury remover and the waste water and sludge treatment method are the same as that of converter.

(4) Catalyst poisoning

Excessive acetylene will cause the reduction of mercuric chloride in the catalyst into calomel or elementary mercury, leading to rapid loss of catalyst activity. This is the so called catalyst poisoning in the industry. Different molecular proportions of acetylene and HCl will lead to different sublimation substances. Current practice of

PVC enterprises is to treat the sublimation substance together with waste mercury catalyst.

(5) Mercury-containing waste alkali

VCM gas from the acid removing system enters the alkali washing tower. Some mercury is absorbed by alkaline fluid generating mercury-containing waste alkali. Mercury-containing waste alkali is neutralized with mercury-containing waste acid from the acid removing system, and the subsequent mercury-containing waste fluid is subject to centralized treatment.

(6) Entering compressing rectification system

With the above processes, most mercury has been carried by waste catalyst, waste activated carbon and mercury-containing waste fluid. Only little mercury ($\leq 1\times10^{-9}$) enters the follow-up processes including compressing rectification of VCM gas.

In view of current mercury reduction measures employed by enterprises, only minor amount of mercury is directly discharged into the environment in the acetylene PVC production process. Most mercury in the waste catalyst is transported to mercury catalyst recycling enterprises with the relevant license for treatment.

3 Difficulties in mercury reduction in PVC industry

China has promulgated and implemented a series of laws, regulations and standards over the past few years to prevent and control environmental pollution from PVC production by the acetylene process, and remarkable achievement has been made in this regard. Higher access conditions to PVC industry by the acetylene hydrochlorination process have, to a certain extent, have curbed the development of small scale enterprises and enterprises with weak capacity in environmental protection. The promotion and application of clean production technology have facilitated standardized management and raised environmental awareness of enterprises. Standardized management of mercury containing waste has facilitated appropriate recycling and reuse of waste mercury catalyst. However, mercury is a heavy metal imposing significant threats to human health and the environment. High toxicity, persistent nature and bioaccumulation potential of mercury will cause persistent and irreversible hazard once it enters the environment. Therefore, the ultimate objective of mercury management lies in reducing or eventually eliminating the use and emission of mercury. It still needs a relatively long transitional period for China’s PVC industry to achieve a mercury free process. With over 100 manufacturers and several million t PVC production, China faces a great challenge during the transition period in terms of technology, policy and funding.

3.1 Lack of mercury reduction technology

China has a relatively weak foundation in the research of mercury-free catalyst. So far there is no research and development results that can be put on trial application. Low-mercury catalyst is only under pilot test (Please see section 2.2.1 in this part), its production technology and application method need further improvement.

Further research and development are needed for the treatment technology during the manufacturing process of mercury catalyst with mercuric chloride as the main active ingredient, such as adding inhibitor, changing preparation process and special treatment of carriers to effectively reduce or inhibit the volatilization and release of mercuric chloride during the application of catalyst and minimize the burden of follow-up treatment.

Current deficiencies include low production capacity of individual fixed bed reactor and hot spots occurred during reaction process. Right now, China still needs to improve the technologies that manufacture and apply new fixed bed reactor or fluidized bed reactor and are able to raise capacity of individual equipment, simplify operation procedure, generate even bulk temperature in reactor, and lower mercury loss during the application of mercury catalyst.

In view of the mercury status in existing manufacturing process, China needs the development and application of high-efficient mercury recycling technology, including high-efficiency mercury adsorption and precipitation technologies to raise mercury recycling and utilization rates and minimize mercury loss and pollution.

Acetylene adding hydrogen technology needs further research and development in order to address mercury pollution problems at the source.

3.2 Management policy in need of further improvement

The government should make continuous efforts in industrial restructuring of the PVC industry to facilitate its sustainable development. Policy measures such as higher access conditions to curb chaotic expansion, clean production auditing, and development of environmental standards should be employed to promote existing enterprises to raise their environmental management cost in order to gradually promote the transition of PVC manufacturers by the acetylene process.

The upstream management of PVC production by the acetylene process needs to be strengthened. The State shall issue relevant policies to regulate the mercury supply, production and supply of mercuric chloride catalyst so that such processes as production and use of mercury catalyst and the recycling, storage, transportation and disposal of waste mercury catalyst are under control.

Current efforts in promoting new technology on mercury reduction are insufficient. For mature mercury reduction alternative technologies or products, the State shall issue relevant policy to promote the use of them. For instance, national government should list the new manufacturing technology on low mercury catalyst into the encouraged category and establish the standard for new low mercury catalyst products in order to gradually phase out the traditional high-mercury catalyst. National government should give policy subsidy to those PVC manufacturers using new low mercury catalyst for a certain period of time to accelerate the dissemination and application of new catalyst.

3.3 Big gap of mercury reduction fund

Because China cannot fully phase out PVC process by the acetylene process in short period of time, it still needs huge amount of capital in such areas as the research and development of new technology and products on reducing mercury, e.g. development of a mercury-free catalyst, new VCM converter and high-efficiency mercury absorbing materials. Moreover, the demonstration of new technology and products also need a great deal of capital.

The capital for promoting the use of new technologies and products is inadequate. The amount of Chinese PVC manufacturers by acetylene process is big but varies in scale. The cost of applying new technologies and products is high, in particular when the technical reformation of the process is required. Some small-scale enterprises cannot afford the cost and need great deal of capital to support the extension and application.

The formulation and improvement of relevant laws, regulations and standards need substantial funds too. This is mainly because of incomplete system for mercury monitoring, outdated testing tools, lack of infrastructure that supports the implementation of laws, regulations and standards, poor capacity and low management level. Huge amounts of funding are needed for capacity building and construction of relevant infrastructure.

4 Plan for PVC industry development

4.1 Focus and direction of industrial restructuring

(1) Strictly control new increment of capacity, establish and improve market mechanism and phase out the out-of-date productivity

Strictly control industrial expansion, prevent trans-region movement of the out-of-date productivity, guide and facilitate the merge and re-organization of chloralkali enterprises, phase out outdated productivity and accelerate industrial reform and upgrading. Set up and improve market mechanisms and strengthen the role of market mechanisms in phasing out outdated productivity and accelerating industrial restructuring. Establish a withdrawal mechanism suitable for the chloralkali industry to accelerate the pace of phasing out outdated productivity.

(2) Optimize industrial layout, prevent blind expansion and low-level redundant construction

Optimize industrial layout and address the issues of scattered layout and redundant construction. Based on existing regional resources, energy conditions and productivity distribution, caustic soda and PVC productivities should gradually move to central and western regions of China rich in coal and electricity. In East China, construction of new acetylene PVC production facility is prohibited, while new large-scale ethylene oxychlorination facilities and projects with multi-utilization of chlorine resources are encouraged. Functional advantages of chemical industrial parks in each region shall be brought into full play to facilitate industrial upgrading. Efforts will be made to promote industrial integration, encourage and support dominating chloralkali enterprises to merge or reorganize lagging-behind or difficult enterprises. Win-win cooperation and upper and downstream integrated operation are encouraged to raise resource allocation efficiency and industrial concentration.

(3) Promote sustainable development of chloralkali industry by independent innovation and technological progress

Enhance innovation with independent intellectual property right, facilitate industrial technology advancement and guide enterprise to adopt new technology and achieve clean production and energy saving and emission reduction. Efforts will be made to facilitate the extension of dry acetylene generation technology, new dry cement manufacturing technology and low mercury catalyst in the industry. We will improve and replicate such new technologies or products as VCM converter fluidized bed technology, new molecular sieve catalyst in PVC production by acetylene process and mercury free catalyst. We will guide relevant enterprises to study and introduce the technologies that curbs mercury pollution at the source, e.g. acetylene hydrogenation technology, DEACON new chlorine manufacturing process and PVC polymerization technology using metallocene catalyst, thus cultivating a group of core technologies and equipment with independent intellectual property rights. We will continuously develop high-value added products that consume alkali and chlorine. The development of PVC products orients toward fine, special and serial products with broader application areas. We will encourage enterprises to employ new technology, process, equipment, materials and facilitate product innovation. We will adhere to the idea of a circular economy and raise energy efficiency in chloralkali industry. With independent innovation and technological progress, we will facilitate sustainable development of the chloralkali industry.

4.2 Analysis on development trend of acetylene PVC industry

4.2.1 Maintain the trend of continuous development

Petroleum is not a renewable energy resource. It is expected that, based on the current oil consumption in the world, oil prices will gradually go up due to the scarcity of the resource. Current price fluctuations are only a kind of reflection of the international financial crisis, being a cyclical market behavior. The development of two process routes for PVC products in China is closely related to the price change of oil and coal. Different process routes will provide different development opportunities in different periods. This kind of economic mode not only meets domestic demand, but also reduces the dependence on petroleum. So it has the conditions and room for long-term development.

The continuous rise of petroleum price in the international market drives the development of PVC production by acetylene process in China. Rich coal and limestone resources and enough power in central and western parts of China as well as the preferential policies on western development, provide exceptionally good conditions for the development of PVC production by acetylene process in China. It is expected that China's PVC production capacity will continue to grow in the next few years. About 70% of the increased productivity will focus on the central and western parts of China.

4.2.2 Industrial development will be subject to strict national regulation

Because the coexistence of two PVC production routes, i.e. the acetylene process and the ethylene process, mercury use cannot be eliminated in PVC production in China until a no mercury catalyst is found for the acetylene process. Therefore, the development of this industry will be strictly regulated by the State due to the mercury pollution problem. The reduction of mercury use and emission becomes one of the challenges that the industry must face and address urgently. The government will take strong measures to address such problems as overheated investment in, and excessive capacity of acetylene PVC production. Relevant enterprises will gradually improve their self-discipline and awareness in controlling risks under strict national regulation. As a result, the PVC industry in China will gradually step onto the track of healthy development.

Part 2 Analysis of policy demand for mercury environmental management in PVC Industry

1 Existing management policy of mercury

Environmental protection laws, regulations and standards in China have developed into a complete system, which provides the relevant legal basis, management system, and technical methods for environmental protection, resource utilization, and pollutant discharge, treatment and disposal. At the same time, environmental protection laws, regulations and standards in China present clear requirements for environmental protection, treatment and disposal of Hg-containing waste and also clearly defined policy development of the acetylene method PVC industry.

1.1 Specific Requirements of laws, regulations and standards

1.1.1 Requirements in the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste

The Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste approved by the 16th meeting of the Standing Committee of the 8th NPC on October 30, 1995 presents clear and detailed provisions on prevention and control of environmental pollution by hazardous waste, and on storage, disposal, transfer and utilization of such waste. MEP and NDRC jointly developed and issued the National Catalogue of Hazardous Waste based on the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste in June of 2008, which went into effect on August 1, 2008.

The requirements relevant to PVC production by carbide acetylene process are the following：

(1) Waste mercury catalyst is a hazardous waste. The solid waste containing the hazardous component $HgCl_2$ is included in “mercury containing waste” in the National Catalogue of Hazardous Waste with hazardous waste code of HW29；

(2) Hazardous waste generating entities shall, in accordance with the regulations on pollution discharge notification and registration developed by environmental protection department, report to the competent environmental protection administrative department of the region where it is located the process where the hazardous waste generates, the amount and pollutant concentration of the waste, and disposal method, etc.;

(3) Any enterprise engaged in the collection, storage and disposal of mercury

containing hazardous waste shall apply for an operation license. It is forbidden to supply or entrust hazardous waste to entities that do not have business licenses for the collection, storage, utilization and treatment of such wastes

(4) Any one who transfers hazardous waste shall, according to relevant national regulations, fill out in duplicate forms and submit the application to the administrative department;

(5) The package and tentative storing site of hazardous waste shall establish hazardous waste identification mark.

1.1.2 Requirements in relevant laws, regulations and standards on energy saving and emission reduction

NDRC distributed the “Recommendations on Strengthening the Administration of PVC Projects with High Energy Consumption and Heavy Pollution according to Law” put forward by NPC at its 14th session on April 17, 2006. The Recommendations state that the top priority is making more efforts in industrial control and facilitating healthy development of the industry strictly in line with national laws and regulations in order to have a breakthrough in replacing carbide PVC production by ethylene oxychlorination PVC production.

NDRC and seven other ministries and commissions jointly issued the “Circular on the Suggestions of Accelerating Industrial Restructuring of Carbide Industry” on April 21, 2006. It identifies the following structural adjustment targets for the carbide industry: thoroughly shutting down and phasing out all carbide furnaces with annual capacity less than 10,000 t, open carbide furnace and those failing to meet emission standards; strictly controlling new carbide projects and banning any new carbide production project in east coastal areas of China.

The national compulsory energy consumption standard “Energy Consumption Limit for Unit Caustic Soda Product” was issued in June of 2008 to support the implementation of the Law of the People's Republic of China on Conservation of Energy. This standard specifies such contents as accounting scope, basic requirement, accounting method and management requirement for the energy consumption limit to unit caustic soda product produced by using the electrolytic method (diaphragm method and ionic membrane method).

1.1.3 Water pollutants discharge standard for caustic soda and PVC industries

The Discharge Standard of Water Pollutants for Caustic Alkali and Polyvinyl Chloride Industry (GB 15581-1995) specifies the differentiated maximum allowable discharge concentration of water pollutants and maximum water discharge per ton of product for caustic alkali and polyvinyl chloride industries according to the construction time of the production facility, and based on the production process and destination of waste water. It is applicable to pollutant discharge management, of the enterprises (including mercury the electrolytic method with salt as raw material, the alkaline fluid manufacturing by diaphragm electrolytic method and the ionic exchange membrane method, the solidifying alkali and chlorine-hydrogen treatment process, as well as the PVC production using hydrogen, chlorine gas, ethylene, carbide as raw materials) of caustic alkali and polyvinyl chloride industry, as well as EIA, design and post-completion check and acceptance of construction projects

The Standard specifies the maximum discharge limit for water pollutants from PVC manufacturers established after July 1, 1996, i.e. the total mercury concentration shall be less than 0.005 mg/L.

1.1.4 Atmospheric mercury emission standards

For general sources of pollution, integrated emission standard of air pollutants (GB16297-1996) limits to mercury emissions: new pollution sources constructed after 1997, the maximum allowable emissions of mercury concentration is 0.012mg/m^3. The highest monitoring concentration limit for the random mercury emissions is 0.0012mg/m^3. This standard is enforced on the atmospheric mercury emission of PVC production process.

For hazardous wastes, the pollution control standards of hazardous waste incineration (GB18484-2001) specifies that the air pollutants emission limits for hazardous waste incineration of mercury and its compounds (as total mercury) is 0.1 mg/m^3. This standard is enforced on the recycling process of waste mercury catalyst, and China accepts and permits the waste mercury catalyst recycling enterprises according to this standard.

1.2 Specific requirements in the《Guide Catalogue for the Adjustment of Industrial Structure》

NDRC amended the Guide Catalogue for the Adjustment of Industrial Structure (2005 Version) based on the Decision of the State Council on Releasing and Implementing the Provisional Regulations on the Promotion of Industrial Restructuring, spirit of No.112 executive meeting of the State Council and new requirement for adapting to industrial restructuring and macro regulations and solicited public comments and suggestions on the Guide Catalogue for the Adjustment of Industrial Structure (2007 Version) In which the requirements for mercury products are mainly as follows:

(1) Encouraged

Article 24 of Chapter 32 “Environmental Protection”: development and application of mercury recycling and treatment technology for Hg-containing waste as well as the manufacture of complete sets of equipment;

Article 3 of Chapter 33 “Resource Conservation and Comprehensive Utilization”: development and application of mercury recycling and treatment technology for Hg-containing waste as well as the manufacture of complete sets of equipment;

(2) Restricted

Article 32 of Chapter 4 “Petroleum, Natural Gas and Chemicals”: Mercuric chloride catalyst projects.

1.3 Specific requirement in the《Conditions for Access to Chloralkali (caustic soda and PVC) Industry》

To facilitate stable and healthy development of the chloralkali industry, prevent low-level redundant construction and improve the comprehensive competitiveness of the industry, NDRC issued the “Conditions for Access to Chloralkali (caustic soda and PVC) Industry” in 2007 based on relevant national laws and regulations and industrial policy and in accordance with the sustainable development principle of “Optimizing layout, appropriate development, adjusting the structure, saving energy, protecting the environment, safe production and technological advance”, which was put into effect on December 1, 2007. The conditions for access to the chloralkali (Sodium hydrate, PVC) industry mainly constrain new or expansion projects in the chloralkali industry in four aspects, i.e. industrial layout, scale, energy consumption and environmental protection.

(1) Industrial layout

The construction of any new PVC production facility by the carbide process and caustic soda manufacturing facilities is prohibited within scenic spots and sites with historic value, nature reserves, protected drinking water source areas, and other areas requiring special protection identified by the State Council, relevant national department, and the people’s government of the province (autonomous region or municipality directly under the central government), within 2 km to the boundary of urban planning zones, two sides along the banks of major rivers, highways, railways and main waterway, within 1 km to the boundary of residential districts and food, pharmaceuticals, sanitary products and precision product enterprises which need strict pollution control, as well as within the environmental protection or safe protection distance identified by national or local governments.

(2) Scale, process and equipment

The initial scale of any new, reformed or expanded PVC facilities must be no less than 300,000 t per year.

Any new, reformed or expanded PVC project adopting the carbide process must install carbide slag comprehensive utilization facilities including a facility that manufactures cement with the slag. The capacity of a single installation using carbide slag to make cement must be no less than 2000t per day. The capacity of supporting carbide-slag cement manufacturing facilities of existing carbide PVC facilities must be no less than 1000 t per day. Any large scale new PVC project adopting carbide process is encouraged to construct big and airtight carbide furnace facilities to achieve a comprehensive utilization of resources.

It is encouraged to replace carbide PVC production technology by ethylene oxychlorination technology. The technological development and technical reform of carbide PVC production process such as acetylene made by dry method, big converter, pressure swing adsorption and mercury-free catalyst are encouraged. The new cement manufacturing facilities using carbide slag as raw materials are encouraged to adopt new dry cement manufacturing process.

(3) Safety, health and environmental protection

Any new, reform or expanding PVC facilities must be designed by a designing institution with qualifications certified by the State and are subject to environment, health and safety assessment conducted by a certified institution. All regulations and standard at national, industry and local levels shall be strictly implemented. The management within the enterprise shall be strengthened. The treatment and disposal of waste mercury catalyst, Hg-containing activated carbon, waste acid, and waste water generated from carbide PVC production facilities must comply with national regulations on hazardous waste, and are subject to strict supervision.

Any new, reformed or expanded PVC facilities must meet all the requirements of "PVC Clean Production Assessment Indicator System" issued by NDRC. PVC manufacturers by carbide acetylene process must develop carbide slag recycling and comprehensive utilization measures. Stockpile or landfill of carbide slag is prohibited.

(4) Energy consumption

It is required that the electricity consumption of the electrolytic unit of any new, reformed or expanded caustic soda facilities shall not exceed 2450 kWh/t. The overall energy consumption of 30% ionic membrane method fluid alkali shall be no more than 350 kg coal equivalent/t. The carbide consumption of any new, reformed or expanded acetylene PVC facilities shall be less than 1420 kg/t (estimated by 300L/kg). The ethylene consumption of any new PVC facilities by the ethylene oxychlorination process shall be less than 480 kg/t.

(5) Supervision and management

Any new, reformed or expanded PVC construction projects will be subject to strict administrative procedures on the review, approval or record according to relevant national regulations on investment management. Any new, reformed or expanding PVC construction projects must get a safety permit, and carry out EIA, follow land use, project record or approval procedures strictly in line with relevant national regulations.

Before putting into operation, any new, reformed or expanding PVC facilities shall be subject to the inspection by a joint inspection group composed of investment, land, environmental protection, safety and quality inspection administrative departments at the provincial level or above and include relevant experts. The joint inspection group will carry out the inspection in accordance with the current access conditions. PVC production facilities shall not carry out trial operations until they meet the access conditions. If such facilities are found through inspection failing to meet the access conditions, the inspection group shall order them to make corrections within a given period of time.

In the case that the new, reformed or expanding PVC production projects fail to meet access conditions, national land and resource administrative departments shall not provide land permits; the work safety supervision department shall not issue safety licenses; the environmental protection administrative department shall not grant environmental approval; the financial institutions shall not issue credit; and the power supplier shall stop the power supply according to law. The local government or relevant competent department shall decide according to law whether to cancel or suspend the project.

1.4 Specific requirement in the《Clean Production Assessment Indicator System of caustic soda/PVC Industry》

The Clean Production Assessment Indicator System of Caustic Soda/PVC Industry was issued in April of 2007, which presents clear requirements for indicators such as resource and energy consumption, amount of pollutants and resource comprehensive utilization of Caustic Soda/PVC industry.

The Clean Production Assessment Indicator System of Caustic Soda /PVC Industry is applicable to chloralkali manufacturers with salt and carbide/acetylene as raw materials to produce caustic soda and PVC. Based on clean production requirements, the current assessment indicator system is divided into two parts: one is the quantitative assessment and the other qualitative assessment. Figure 4 and Figure 5 show the quantitative assessment indicator system and qualitative assessment indicator system.

Through the application of the Clean Production Assessment System, the standardized management of the acetylene PVC production process and the improved environmental awareness and operation skill of workers are conducive to reduce unnecessary consumption and emissions of mercury in the production process.

Figure 4 Clean Production Quantitative Assessment Indicator system for caustic soda/ PVC Industry

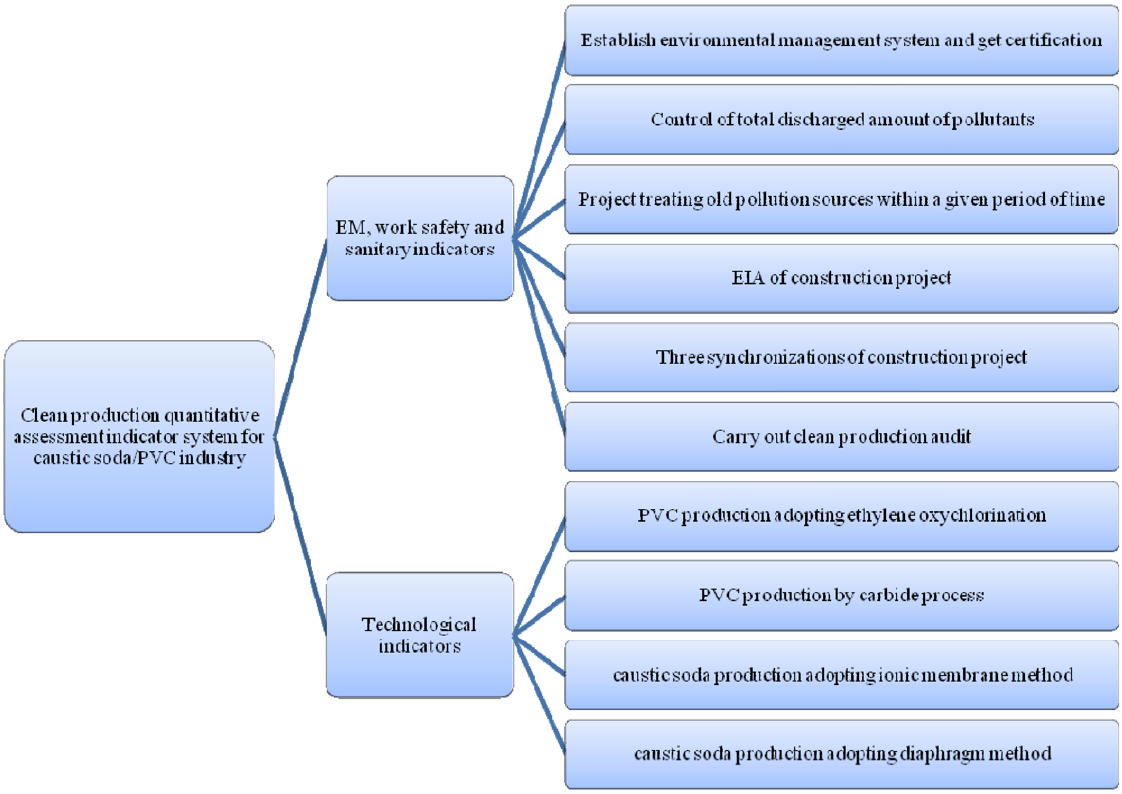
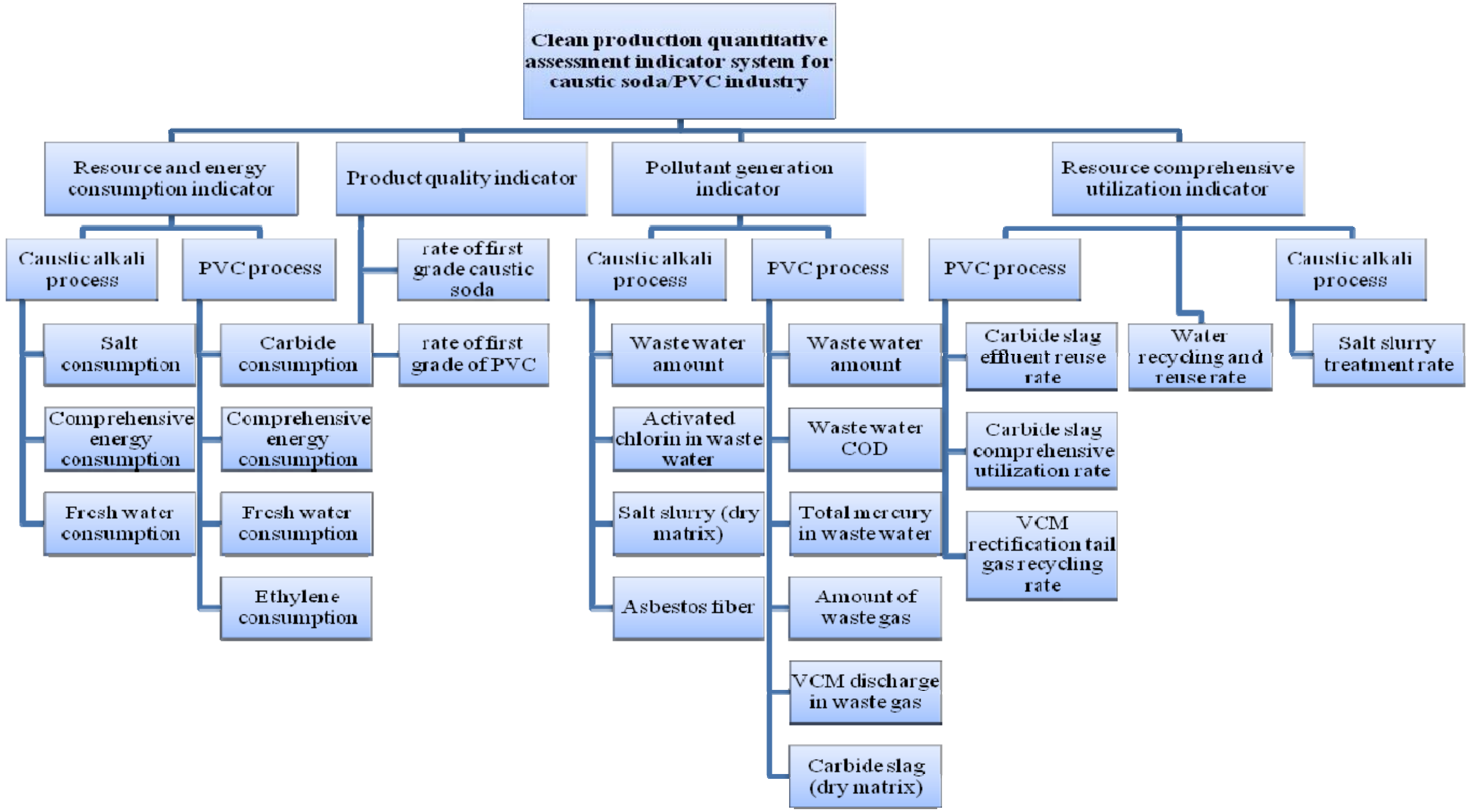


Figure 5 Clean production quantitative assessment indicator system for caustic soda/PVC industry



1.5 Specific requirements in the《Guide Catalogue for Foreign Investment》

NDRC and Ministry of Commerce issued an announcement stating that the Guide Catalogue for the Foreign Investment in Industries (2007 Amendment) is put into effect on December 1, 2007 and the Guide Catalogue for the Foreign Investment in Industries (2004 Amendment) is nullified at the same time. The catalogue encouraged foreign investment industries to include PVC resin production (ethylene process) with annual capacity no less than 200,000 t, while the PVC production by carbide process is restricted.

2 Existing problems in management

PVC production by acetylene hydrochlorination in China has developed into a big industry with a total asset value as high as several hundred billion Yuan RMB and great room for further growth. But the PVC industry is faced with several constraints regarding such factors as environment, technology and capital, which need to be addressed.

2.1 Development of the industry

As a production process that cannot be fully phased out in China, PVC production by the acetylene process shall be subject to strict management and control in terms of its development due to the risk of mercury to human health and the environment. The ultimate objective shall be to fully phase out the use of mercury catalyst. Although current laws and regulations have taken certain countermeasures in such aspects as production scale, environmental protection requirement for the production of carbide (raw material) and the manufacture of mercuric chloride catalyst, there remain problems in terms of the overall development of the industry.

（1） Continuous expansion of the industry

China's PVC industry has undergone rapid development over the past few years, and the acetylene PVC production has been growing even faster by taking advantage of rich resources, which accounts for a high proportion of the whole PVC industry. Taking 2008 as an example, though the development of carbide PVC industry was under an unfavorable environment including downturn of oil price and new domestic administrative policies such as the 300,000 t access conditions and higher environmental protection requirements, China's carbide PVC production capacity reached 11.605 million tons accounting for 73.4% of the total PVC production capacity(15.81 million tons). Therefore, the carbide PVC production in

China is expanding and there is still room for rapid development in the next few years.

One thing that deserves special attention is the relatively low operating rate of PVC facilities adopting the acetylene process and the gap between output growth and capacity growth, particularly in 2008. Capacity growth represents the overall potential of PVC output increase. PVC output will have rapid growth once ideal conditions for economic development are in place. This is not optimal for overall reduction of mercury utilization and consumption in the PVC industry.

（2） Insufficient scale production

China has many small PVC manufacturers adopting the acetylene process with annual capacity less than 100,000 t. In 2008, there were 38 such small manufacturers, taking up 42.7% of the total, but their total capacity was only 1.705 million t, accounting for 14.6% of the total output. (Please see Table 2 in the first part of this report.) Small enterprises have low economic strength and evidently lower capacity to implement environmental protection measures than large enterprises. In addition, higher mercury consumption per unit product of such enterprises constrains the extension and application of alternative products or technology as well as new mercury-reducing technologies and measures, which is not conducive to healthy development of the industry.

（3） Insufficient upstream management

Regulation and management of the manufacture and supply of mercuric chloride catalyst – the upstream product of PVC production by the acetylene process - is vital for the overall development of the industry. China's administrative policies have touched upon this. The Guide Catalogue for the Adjustment of Industrial Structure issued in 2007 lists mercuric chloride catalyst projects into the restricted category. The conditions for industrial access also encourage the development and application of mercury-free catalyst technology. However, there is no clear control measure for the administration of the sources of raw materials and product supply of mercury catalyst. For example, control the production of $HgCl_2$ catalyst by controlling the mercury supply to mercury catalyst manufacturers, or control the supply to PVC manufacturers is controlled by regulating $HgCl_2$ catalyst product supply. Strengthening the control and management of production and supply of $HgCl_2$ catalyst is conducive to curb the chaotic expansion of the acetylene PVC industry, gradually reducing the dependence on and demand for mercury by the industry, as well as facilitating the extension and application of low mercury or mercury-free catalyst products.

（4） Slow research, development and promotion of alternative products or technologies

China has made a breakthrough in the development of low mercury catalyst over the past few years. With its manufacturing technology becoming mature, the low mercury catalyst has been put in trial use in many enterprises with good results. The application of low mercury catalyst leads to about 50% reduction of mercury consumption in the PVC industry. The low mercury catalyst is a method for Chinese PVC manufacturers to reduce the amount of mercury used in the process.

However, the extension efforts in low mercury catalyst in China clearly lag behind the industrial development. This is simply reflected by the fact that there are no clear requirements for adopting low mercury catalyst in new, reformed and expanding projects and insufficient policy support to the application of low mercury catalyst in existing enterprises, thus leading to slow application of low mercury catalyst and low rate of mercury reduction in the industry. In addition, national support to the research and development of mercury free catalyst should be enhanced. The application of mercury free catalyst is a must for the health and sustainable development of China's PVC industry.

2.2 Environmental protection

In the transitional period when China cannot fully phase out $HgCl_2$ catalyst, the environmental protection in PVC production is critical. How to minimize mercury utilization and emissions should be the focus of environmental management. In view of current management, PVC enterprises still need to address a series of problems for environmental protection.

（1） Local administrative departments and enterprises lack awareness in environmental protection

It is common for enterprises to have a poor understanding about the hazard of mercury pollution and a low environmental awareness, in particular the PVC manufacturers. The main environmental problem of this industry is the large application amount of mercury and the generation of a large amount of Hg-containing waste. However the mercury discharge amount in the production process is very little, and its direct health impact on workers is relatively small, adding the weight of ignorance to environmental protection measures. The existing Chinese laws and regulations only cover the discharge of Hg-containing waste water, air, and recycling and treatment of Hg-containing waste. There are no clear regulation requirements for mercury use and supply, and there is no monitoring of mercury in the ambient environment.

（2） Need to further improve mercury monitoring system

It is clearly stipulated in national pollutant discharge standard that the maximum allowable mercury concentration of the discharged waste water from PVC production facilities which was established after July 1, 1996 is 0.005 mg/L. The implementation of this standard has enhanced the attention of PVC enterprises to the treatment of Hg-containing waste water and facilitated the extension of effluent recycling and reuse technology in the industry. At present, PVC manufacturers in China basically achieve 100% recycling and reuse of industrial effluent. Although there is standard for mercury atmospheric emission, there is no monitoring system on mercury atmospheric emission during PVC production by acetylene hydrochlorination is an important source of mercury atmospheric emission. Although not big in emitting amount, its long-term accumulated amount is significant, imposing long-term risks to human health and the environment. It should be a focus for the prevention and control of mercury pollution.

（3） Lack unified and standard guidance and management on corporate operation process

There are several links in the acetylene PVC production process where mercury release may happen, such as tentative storage of $HgCl_2$ catalyst, replacement of catalyst and the activated carbon, dumping of waste catalyst and activated carbon, clearing and dumping of sludge, and collection and storage of Hg-containing waste acid. Improper management will greatly increase mercury loss. Right now, there are no unified and standard requirements for the above-mentioned issues. There is no practical standard for enterprises to follow. The management level varies greatly among enterprises. All these lead to unnecessary mercury loss. This is especially true for small enterprises.

3 Policy demand analysis

3.1 Necessity for the development of mercury management policy

With rapid development of the PVC industry adopting the carbide acetylene process, the proportion of such manufacturers is becoming higher and higher. However, the development of this industry is, to some extent, restricted by national policies regarding the high energy consumption and certain pollution control requirements during the production of carbide, the raw material for acetylene PVC production. This is in conflict with relevant national policies such as energy saving and emission reduction. When there is low energy consumption and relatively good environmental performance, PVC production by the ethylene process becomes the industry being encouraged by national policies. However, relative lack of ethylene supply in China leads to the co-existence of the two PVC manufacturing processes in a relatively long period of time. Therefore how to reduce or even eliminate mercury utilization and emission in carbide PVC production is the urgent priority for the development of the industry.

The analysis of existing industrial policies shows that current Chinese administrative policies are dominated by the guiding, administrative and standard ones. China lacks both management tools with strong binding forces and specific economic incentive policy. The analysis of existing environmental protection policies demonstrates that there is an obvious weakness in source control and pollution prevention. This leads to a series of problems in the development and environmental protection of the PVC industry using the acetylene process.

To sum up, future environmental management policy of the PVC industry in China should target the mercury life cycle. Systematic management countermeasures should be developed focusing on source control, process supervision, clean production and environmentally sound treatment of mercury waste. Centering on the comprehensive utilization of mercury-free alternative products and technologies and making the shift to mercury-free process, mercury use and emissions will be gradually reduced and eventually eliminated in the acetylene PVC industry. There is also a need to normalize mercury related management in the industry through employing economic incentives, binding and voluntary control measures, and economic mechanisms.

3.2 Policy demand and management measures

The required management policies targeting on mercury lifecycle and specific measures are seen in Table 3.

Table 3 Policy demand for regulating mercury in PVC industry and specific measures

Hg life cycle	Policy demand	Specific measures
Production, import and export of mercury	Strictly regulate and control mercury import and export	1）Improve the existing import and export registration system for mercury and its compounds, trace the sources 2) Limit the supply of imported mercury to $HgCl_2$ catalyst enterprises

	Strictly administrate mercury production and recycling enterprises	3) Implement mercury production license system 4) Implement mercury recycling license system (Implemented) 5)Implement notification and registration system for the movement of manufactured or recycled mercury, limit the supply to $HgCl_2$ catalyst enterprise
Production and supply of $HgCl_2$ catalyst	Restrict the production of $HgCl_2$ catalyst	1）Implement $HgCl_2$ catalyst enterprise license system 2）Carry out the total amount control of $HgCl_2$ catalyst production
	Restrict the supply of $HgCl_2$ catalyst	3) Implement notification and registration system for the movement of $HgCl_2$ catalyst
	Promote the use of low mercury catalyst	4) Develop low mercury catalyst product and production standard 5) Policy incentive to low mercury catalyst production projects
	Promote the research and development of mercury free catalyst	6) Increase the fund for R&D of mercury-free catalyst as a priority for PVC sector development in China, and implement research program 7) Encourage international cooperation on mercury-free catalyst technology
PVC production	Reduce mercury utilization in PVC production	1) Integrate the application of low mercury catalyst and, no mercury catalyst when available, into clean production indicator system of PVC industry 2) Grant rational economic compensation to enterprises using low mercury catalyst

	Reduce mercury consumption and emission during PVC production	1）Develop and implement Hg atmospheric emission standard 2) Set up mercury atmospheric emission monitoring system 3) Carry out notification and registration system for mercury pollutant discharge 4) Establish clean production indicator system targeting on mercury use and emissions, and carry out compulsory clean production audit on PVC manufacturers by acetylene process 5) Encourage the R&D and application of Hg-reducing new technologies and measures 6) Integrate environmentally friendly storage and collection of Hg-containing materials and waste into corporate clean production audit
Treatment and disposal of mercury containing waste	Strict management of the treatment and disposal of mercury containing slag	1) Carry out annual report system for Hg-containing slag treatment enterprises 2) Monitoring and managing Hg-containing slag treatment and disposal process to avoid secondary pollution 3) Encourage the recycling and reuse of mercury in Hg-containing slag
	Strict management of the treatment and disposal of mercury containing waste acid	4) Carry out annual report system for Hg-containing waste acid treatment enterprises 5) Monitoring and managing Hg-containing waste acid treatment and disposal process to avoid secondary pollution

3.3 Work in the next stage

(1) Raise the awareness of environmental management departments and enterprises on the risk of mercury pollution;

(2) Make more efforts in promoting the use of low mercury catalyst and development of mercury-free catalyst, continually reducing mercury utilization in PVC industry by the acetylene hydrochlorination process;

(3) Develop more effective economic instruments and other policies to strictly control chaotic expansion of PVC industry by acetylene process;

(4) Carry out BAT and BEP demonstration projects and facilitate mercury reduction of the industry;

(5) Initiate the work of establishing the mercury emission inventory of PVC industry. Develop mercury reduction target and plan to guide the mercury prevention and control of China’s PVC industry.