UNEP

Socio-economic Analysis on Mercury Thermometer and

Sphygmomanometer Transition towards Mercury Free Products in China

—

Hypothetical Transition Scenarios Analysis and Socio-economic Cost Estimation

Supported by: UNEP DTIE Chemicals Branch

Prepared by: Chemical Registration Center of MEP

December 2012

Index

Introduction

Mercury thermometer and manometer are widely used in China and exported to many countries and regions in the world due to their accuracy, inexpensiveness, and simplicity and convenience in use. At present, the annual output of mercury thermometer and sphygmomanometer is over 100 million and 3 million respectively in China.

To facilitate the transition towards mercury free thermometer and sphygmomanometer and the reduction of mercury use and emission, a study project on the social and economic impact of the transition towards mercury free products was funded by the United Nations Environment Programme (UNEP), aiming at understanding the progress of research and development of mercury free products and the social-economic costs of transition, analyzing the social and economic impact of mercury free transition.

The project was implemented by the Chemicals Registration Center of MEP with the assistance of the Chinese Association of Medical Devices Industry (CAMDI). By conducting survey on the industry and individual enterprises, the status quo of the production of mercury thermometer and sphygmomanometer in China is understood and the production cost, manufacture cost, R & D cost of mercury free products, market costs as well as other economic cost data related to technological transition were obtained for the enterprises being investigated, based on which transition scenarios were hypothesized and social and economic costs of different scenarios have been estimated. During the implementation of the project, three workshops and one experts' reviewing meeting were held in which participating experts of relevant fields and representatives of enterprises discussed the feasibility of substituting mercury thermometer and sphygmomanometer with mercury free products and explored the fund requirement for this substitution, thus ensuring the objective credibility of the project outcomes.

Based on different hypothetical scenarios, the report analyzed and extrapolated the costs of conversion to mercury free thermometer and sphygmomanometer in China, and the report conclusion does not represent the views or position of MEP.

1. Background

1.1. Project background and objectives

The project of the Socio-economic impact of Conversion to Mercury Free Products was funded by United Nations Environmental Programme (UNEP), in order to help facilitate the transition towards mercury free thermometer and sphygmomanometer and the reduction of mercury use and emission. Based on the current production status of mercury-added and non-mercury products and investigation of enterprises' economic costs of mercury added thermometer and sphygmomanometer, non-mercury thermometer and sphygmomanometer, the case study has tried to extrapolate the cost of conversion of the whole sector by analyzing the social and economic impacts, and the problems and challenges arising from the mercury free transition process.

The objectives are as follows:

- Production status of mercury-added and non-mercury products (thermometer and sphygmomanometer) in China
- Economic costs of transition to non-mercury alternatives
  Economic elements in the case studies include: research and development costs, manufacturing costs, marketing costs and other costs saved or incurred in the technological shift; investment payback period
- Extrapolation of study results to the entire sector
- Workshop for information exchange
- Financing options for transition costs

The project was implemented according to the above objectives.

1.2. Project implementation process

The composition of transition costs and estimation methods were determined and the basic data were collected through ways of documentation and information analysis, questionnaires, interviews with enterprises by phone, etc. The following activities were carried out to ensure that the estimation methods and results are objective and rational.

- In July 2011, the kick-off meeting was held to determine the implementation scheme of the study project.
- In August 2011, the workshop of economic experts was held to determine

the estimation methods.

- In December 2011, the workshop attended by the experts of sector, enterprises and relevant fields to exchange the views on the basic data for the estimation and the value getting methods.
- In February 2012, project draft report presentation and discussion.
- In March 2012, experts review meeting was held to collect the comments and suggestions on the project report.

1.3. Estimation methodology

According to the project requirements, only the incremental costs of mercury free transition were estimated in the report, excluding the estimation of the environment and health benefits and the offsetting estimation between costs and benefits.

The report adopted incremental costs as the main estimation method, and the increased costs during transition are positive and the decreased costs are negative. Based on the known enterprises' numbers, production capacity, production output and other sector statistics, the average value of the industry used in the cost estimation was extrapolated from the basic data of the representative enterprises being surveyed. The cost is estimated by employing those methods commonly used in economics and combining certain hypothetical scenarios. Although the worst case assessment has been applied to the specific transition costs, the practical assessment should be in accordance with the control measures of the Convention. During the estimation process, the hypothesis of different scenarios and assignment of value may cause some uncertainties. The results may need adjustments according to the national economic growth, sector development and availability of basic data.

1.4. Investigation methods

The enterprises are investigated mainly in the way of questionnaires. The design of questionnaire has adequately considered the basic data requirements for costs estimation. Table 1-1 and 1-2 are the questionnaires being filled by thermometer and sphygmomanometer manufacturers.

Table 1-1 Questionnaire Sample for thermometer manufacturers

Company Name：			
Address：			
Contact：	Phone No.：		
Established Date (year)：	The latest investment date (year)：		
Names of Products	**Mercury Thermometer**	**Galinstan Thermometer**	**Electronic Thermometer**
Total Investment (10 thousand yuan)			
Production capacity (10 thousand)			
Production output (10 thousand)			
Sales volume (10 thousand）			
Export volume (10 thousand)			
Annual output value (10 thousand yuan)			
Patent transfer (10 thousand yuan)	/		
Or independent R & D (10 thousand yuan)	/		
Sale price of unit product (yuan)			
Production cost of unit product (yuan)			
Service life of product (year)			
Number of workers (people)			
Local average level of wages (10 thousand yuan/year)			
Compensation years for worker layoff (year)		/	/
Area of the factory premise (m^2)			
Remediation cost (yuan/ m^2)		/	/
Fixed assets (10 thousand yuan)			
Equipment service life (year)			
Spent equipment service life (year)			
Labor cost for production equipment disposal (10 thousand yuan)		/	/
Investment in equipment modification (10 thousand yuan/10 thousand thermometer)	/		
Investment payback period (year)			
Incremental cost of in-stock product and mercury-containing waste treatment and disposal (10 thousand yuan)		/	/
Regulatory compliance cost (10 thousand yuan)		/	/

Note：All fill-in data refer to that of 2010 if not indicated otherwise

Table1-2 Questionnaire Sample of Sphygmomanometer manufactures

Company Name：			
Address：			
Contact：	Phone No.：		
Established Date (year)：	The latest investment date (year)：		
Names of Products	**Mercury Sphygmomanometer**	**Electronic Sphygmomanometer**	**Aneroid Sphygmomanometer**
Total Investment (10 thousand yuan)			
Production capacity (10 thousand)			
Production output (10 thousand)			
Sales volume (10 thousand）			
Export volume (10 thousand)			
Annual output value (10 thousand yuan)			
Patent transfer (10 thousand yuan)			
Or independent R & D (10 thousand yuan)			
Sale price of unit product (yuan)			
Production cost of unit product (yuan)			
Service life of product (year)			
Number of workers (people)			
Local average level of wages (10 thousand yuan/year)			
Compensation years for worker layoff (year)			
Area of the factory premise (m^2)			
Remediation cost (yuan/ m^2)			
Fixed assets (10 thousand yuan)			
Equipment service life (year)			
Spent equipment service life (year)			
Labor cost for production equipment disposal (10 thousand yuan)			
Investment in equipment modification (10 thousand yuan/10 thousand manometer)			
Payback period (year)			
Incremental cost of in-stock product and mercury-containing waste treatment and disposal (10 thousand yuan)			
Regulatory compliance cost (10 thousand yuan)			

Note：All fill-in data refer to that of 2010 if not indicated otherwise

With the assistance of CAMDI, the questionnaires were sent out to the known thermometer and sphygmomanometer producing enterprises with different production scales and different types of products. Some enterprises considered the survey data as their commercial confidential information, and cannot put them in the questionnaires. Only 4 enterprises have returned thermometer questionnaires, of which the market share is about 59.2% with the highest one of 23.3% and lowest of 1.7%; and 3 enterprises have returned sphygmomanometer questionnaires, of which the total market share is 88.5% with the highest one of 58.7% and lowest of 9.2% (Table 1-3). In terms of market shares and production scales, the investigated enterprises are representative, including large, middle and small production scale ones, of which the data can be used in the estimation.

Table 1-3 the Market Shares of Investigated Enterprises

Sector	**Enterprises**	**Production capacity (10 thousands)**	**Production output (10 thousands)**	**Market share （%）**
Thermometer manufacturing	Company A	3500	3500	23.3
	Company B	2900	2650	17.6
	Company C	3000	2500	16.6
	Company D	300	250	1.7
	Total	9700	8900	59.2
Sphygmomanometer manufacturing	Company B	300	191	58.7
	Company E	66	67	20.6
	Company C	36	30	9.2
	Total	402	288	88.5

1.5. Glossary and explanation

All the terms involved in the socio-economic analysis are listed and defined in the table 1-4.

Table 1-4 Glossaries

Terms	Explanation
Profit loss of manufacturing enterprises	It indicates the profit loss to enterprises due to shutting down the production of mercury-added products.
Losses of wages and benefits and capacity building cost	The former workers with their previous production skill could not meet the requirements for mercury free product production, thus needing compensation used for re-employment training.
Technology introduction cost	The financial support will be provided to some enterprise or institution to conduct mercury free technological R&D or technology introduction, and then the research results are to be released to the whole sector.
Investment in alternative equipment and infrastructure construction cost	As to the different production technology and processes, it is imperative to modify and build the infrastructure, purchase new equipment.
Incremental cost of mercury products and equipment treatment	It includes the treatment cost of the in-stock products, semi-finished products and mercury-containing waste, and the labor cost of once-for-all treatment for original production equipment and wastes treatment facilities.
Cost for environmental remediation	It indicates the cost to clean up and remedy the production workshops and surrounding area that may be contaminated by mercury.
Cost of regulation formulation	It indicates the cost to study, develop or revise policies, regulations and standards related to substituting mercury free alternatives for mercury thermometer and sphygmomanometer.
Cost of supervision and administration	It indicates the cost to train the relevant regulatory departments about the development and implementation of the policies and regulations, and the cost to conduct demonstrative projects of medical institutions on the use of mercury free products.
Incremental purchase cost by buying alternatives	The consumers need to pay for the incremental purchase cost as the price of alternatives is higher.
Incremental service cost by using alternatives	The consumers need to pay for the incremental service cost as the way of use and maintenance costs of mercury free products are different from that of mercury-added products.
Training cost for using of mercury free products	It indicates the cost to train the consumers and medical institutions on the use of mercury free products.
The burden of government aiding poverty-stricken areas	As to the economic situation, the government needs to provide financial aiding to poverty-stricken areas for mercury free transition.

Regulatory compliance cost	It indicates the saved cost related to mercury pollution prevention and control, including relevant environmental management cost and mercury-containing waste treatment cost.
Environmental management cost	It mainly consists of those economic costs incurred by environmental monitoring, regular health check of workers, training of workers, data reporting, etc.
Mercury-containing waste treatment cost	It mainly includes the economic costs for purchasing environmental protection facilities and their operation, and for the routine treatment and disposal of mercury-containing wastes resulting from the regular production of mercury-added products.
Health benefit	The mercury free transition would not only insure the worker's health, but also protect more customers to some extent from risking mercury exposure.
Environment benefit	The benefit results from the reduction of mercury-containing wastes generated and discharges from mercury mining and smelting, contaminated site remediation and etc.

2. Production and management status quo of thermometer and sphygmomanometer in China

2.1. Status quo of production

In recent years, the medical devices industry in China has been developing rapidly. There are more than 16,000 manufacturers, of which the number of enterprises with annual sales value of more than 100 million yuan is about 200, and nearly half of them are wholly foreign-owned or joint venture enterprises. The use of mercury in medical devices industry is mainly concentrated on the production of mercury thermometer and sphygmomanometer. According to the survey of CAMDI, there were about 26 enterprises producing mercury-added products nationwide in 2010, including 21 mercury thermometer producing enterprises and 7 mercury sphygmomanometer producing enterprises, most of which are small and middle-sized enterprises. In 2010, the production capacity of mercury thermometer was approximately 183 million, production output of about 150 million, annual output value of about 275 million yuan, and employee of about 3,000; the production capacity of mercury sphygmomanometer was approximately 4.18 million, production output of about 3.25 million, annual output value of about 657 million yuan, and employee of nearly 2,500.

Currently, the mercury thermometer is the major medical equipment for daily measurement of body temperature, and its main working substance is mercury (pure mercury) with the purity of higher than 99.99%. Thermometer is usually divided, according to different purposes of use, into the armpit, oral, rectal and veterinary thermometer, and the production output of oral and rectal thermometer is higher than other thermometers, accounting for 70.21% and 29.46% of the total production output.

The mercury sphygmomanometer is also the common medical equipment in daily life. The main material is liquid mercury, and its purity is higher than 99.99%. The product is generally divided into the sphygmomanometer with manual switch and automatic switch, of which the mercury content is different.

2.2. Status quo of management

The production and use of mercury thermometers and sphygmomanometers have potential hazardous effects on the environment, patients and medical personnel. The developed countries and regions have put in place relevant policies or regulations to control the production and use of mercury products, while China also gradually intensifies the development and introduction of mercury free products.

China, as the large producer of mercury thermometer and sphygmomanometer, pays more attention to mercury pollution related to the production and use of these two products in recent years, and strengthens the source management. In March 2011, the National Development and Reform Commission (NDRC) issued the "Guiding Directory of Industrial Restructuring (2011 edition)," placing the new construction, renovation, expansion of mercury-added glass thermometer and sphygmomanometer manufacturing facilities into the restricted category, which was put into effect in June 2011. The introduction of the policy has played a guiding role in promoting the transition of mercury thermometer and sphygmomanometer manufacturers.

For the whole medical device industry, though the environmental factors have not yet become the essential requirements of market access for medical device manufacturers and products, the country has been encouraging the independent innovation of digital, informationized and smart medical devices. To promote the electronic thermometer, the “calibration specifications of clinical electronic thermometer” (JJF 1226-2009) was officially implemented in 2009 to unify the performance evaluation methods for electronic thermometer. The specification is favorable to standardize the production and use of electronic thermometer, having important significance for proper use of electronic thermometer and obtaining reliable measurement data, and also contributes to the development of electronic and other environment friendly thermometers, which is beneficial to the mercury free transition. Transition to mercury free sphygmomanometer has many advantageous factors as well. The application scope of electronic sphygmomanometer is gradually expanding, and mercury free products are being accepted by more and more hospitals and families.

Nevertheless, we are still facing many difficulties and challenges in terms of production technology and promotion of mercury free products in China. For thermometers, although the electronic thermometer has such advantages as safer to use, better performance and shorter measurement time than the mercury thermometer, but the price and accuracy (affected by the power and environmental factors) still leave much to be desired. Moreover, as the core part of electronic thermometer, the electronic chips are still imported from Europe, the United States, Japan, China Taiwan and other regions. Similar to the above mentioned circumstances of electronic thermometer, the performance of some mercury free sphygmomanometers are not stable. Besides, the electronic chips are technically immature and the ratio of performance and price is relatively lower than mercury products. Also those are the domestic practical problems existing in the production and use of mercury free products. Therefore, if the mercury thermometer and sphygmomanometer were replaced by mercury free products, it would be necessary to estimate scientifically and objectively the social and economic costs involved in the course of mercury free transition, and to solve the technical and funding problems during the transition process.

3. Analysis of mercury free transition scenarios

At present, the alternative products of mercury thermometer in China are mainly galinstan thermometer and electronic thermometer, also with small quantity production of disposable thermometers. The alternatives of mercury sphygmomanometer are mainly electronic sphygmomanometer and aneroid sphygmomanometer. The above mercury free products are the dominant products that are produced, sold and used in China.

3.1 Introduction of mercury free alternative products

3.1.1. Galinstan thermometer

Galinstan thermometer employs a mixture material of gallium, indium and tin as the temperature medium, which expands with temperature to provide a reading on the scale. The shape and general principle of galinstan thermometer is the same as mercury thermometer, but the internal temperature-sensing medium is changed into liquid alloy made up of six metal elements. This type of thermometer has the same measurement accuracy as mercury thermometer (+0.1°C and -0.15°C) and similar stability. It needs mandatory inspection only one time before delivery until abandoned as inaccuracy, and requires no calibration in the course of using.

Galinstan thermometer is improved from three aspects: overcoming the instability of eutectic point alloy by using the new mixture material which is of eutectic point, high vaporization point and better stability below 5°C; Owing to adjusting the two cross sections of necking that is between the tube and sphere showing temperature, the thermometer function was maximized; the manufacturing process is simple and feasible and also reduces the harms to the environment. Its market position is on medical institutions for diagnosis.

3.1.2. Electronic thermometer

The electronic thermometer is made up of temperature sensor, LCD display, button battery, Application Specific Integrated Circuit (ASIC) and other electronic components. Electronic thermometer operation is based on the principle that the temperature sensor outputs digital signal directly, or current signal that is transferred into the digital signal recognizable by internal integrated circuit, and then the display (e.g. LCD, digital tube, LED matrix, etc.) shows the temperature in digital form to record and read the maximum value. The key component is the NTC temperature sensor, of which the resolution is up to ± 0.01°C, and the accuracy of up to ± 0.02°C.

Compared with traditional mercury thermometer, the electronic thermometer has the following advantages: easy reading, shorter measuring time, higher accuracy, with a tolerance of less than ± 0.1°C. However, the measurement stability is relatively low.

In accordance with the “Relevant provisions of implementing inspection of measuring instruments which need compulsory inspection (trial)” ((1991) No. 374) by General Administration of Quality Supervision, Inspection and Quarantine of China, the electronic thermometer needs mandatory inspection only one time before delivery until abandoned as inaccuracy. It is no need to be calibrated in the course of using.

3.1.3. Electronic sphygmomanometer

The electronic sphygmomanometer, using the oscillometric technique, comprises a pressure sensor and a microprocessor. During cuff deflation, a pressure sensor transmits an electric signal to a microprocessor that translates the signal to systolic and diastolic blood pressure. It can also display the comprehensive information about blood pressure patterns besides systolic and diastolic blood pressure, which may be useful for diagnostics. In accordance with the “Relevant provisions of implementing inspection of measuring instruments which need compulsory inspection (trial)” ((1991) No.374) by General Administration of Quality Supervision, Inspection and Quarantine of China, the electronic sphygmomanometer needs regular inspection.

Table 3-1 shows the international manufacturers and prices of the typical electronic sphygmomanometers.

Table 3-1 Typical Manufacturers of Electronic Sphygmomanometers

Manufacturer	Location	Website	Model	Price (USD)
A&D Medical	San Jose, California, USA	www.andmedical.com	UA-766-PV	$89.95, (Promed)
Homedics	Commerce Township, Michigan, USA	www.homedics.com	BPA-300	$99.95, (Promed)
Omron Healthcare Inc.	Kyoto, Japan	www.omronhealthcare.com	HEM-711 DLX	$99.95, (Promed)

3.1.4. Aneroid sphygmomanometer

Aneroid sphygmomanometer, also called pointer mechanical sphygmomanometer, uses the auscultatory method to measure blood flow. It consists of a dial that reads in units of 0 to 300 millimeters of mercury and a fine brass corrugated tube that is responsive to changes in pressure. In accordance with the “Relevant provisions of implementing inspection of measuring instruments which need compulsory inspection (trial)” ((1991) No.374) by General Administration of Quality Supervision, Inspection and Quarantine of China, the aneroid sphygmomanometer needs regular inspection.

Table 3-2 shows the international manufacturers and prices of the typical aneroid sphygmomanometers.

Table 3-2 Typical Manufacturers of Aneroid Sphygmomanometers

Manufacturer	Location	Website	Model	Retail Price (USD)
A&D Medical	San Jose, California, USA	www.andmedical.com	UA-200	$39.95, (Promed)
American Diagnostic Corp.	Hauppauge, New York, USA	www.adctoday.com	Diagnostix 703	$66, (Nextag)
BV Medical Standard	Barrington, Illinois	www.bvmedical.com	BV-115M	$20.93, (Healthy)
GF Health Products Inc.	Atlanta, Georgia, USA	www.grahamfield.com	Labtron Series, 03-202S	$39.95, (Promed)
MDF Instruments	Agoura Hills, California, USA	www.mdfeurope.com	MDF808B,	$41.08, (Healthy)
Omron Healthcare Inc.	Kyoto, Japan	www.omronhealthcare.com	115M,	$22.04, (Healthy)
Trimline Medical Products Corp.	Raritan, New Jersey, USA	www.trimlinemed.com	Numerous Models	Not readily available.
W. A. Baum	Copiague, New York, USA	www.wabaum.com	Pocket Series	$49.98, (AllHeart)
Welch Allyn Tycos	Skaneateles, New York, USA	www.welchallyn.com	Pocket Aneroid	$117.98, (AllHeart)

3.2. Hypothesis and analysis of transition scenarios

Given the status quo of the production and sales of the mercury free alternatives of mercury thermometer and sphygmomanometer in China, two routes are considered for the transition of mercury thermometer: galinstan and electronic thermometer, while two routes for the transition of mercury sphygmomanometer: electronic and aneroid sphygmomanometer. Mercury sphygmomanometer cannot be completely replaced by mercury free alternatives because it is needed in the measurement for some special patients. So the transition scenarios are suggested as follows:

Transition of Mercury Thermometer:

Scenario 1: Full transition from mercury products to galinstan thermometer production. Only a few enterprises in China possess the patented technology.

Scenario 2: Full transition from mercury products to electronic thermometer production. No enterprise in mainland China owns patented technology of electronic chip.

Transition of Mercury Sphygmomanometer:

Scenario 1: Partial transition from mercury products to electronic sphygmomanometer production. No enterprise in mainland China owns patented technology of electronic chip. The electronic sphygmomanometers are divided into household and medical products, of which the production technologies and prices are different. The medical electronic sphygmomanometer has not been considered in the transition scenario in the report as no domestic enterprise has the capability to produce it.

Scenario 2: Partial transition from mercury products to aneroid sphygmomanometer production.

4. Cost composition of transition and its influence factors

4.1. Cost composition of transition

The cost for the transition from mercury thermometer and sphygmomanometer to mercury free thermometer and sphygmomanometer includes two parts: enterprise's economic cost of phasing out mercury-added products and social cost of phasing out mercury-added products.

The economic cost of enterprise for phasing out mercury-added products should include the incremental costs incurred by producing mercury free products of both enterprises producing mercury products and the upper-stream mercury producing and processing enterprises. According to the project requirements, only the transition costs of mercury products producing enterprise was estimated in the report, and the transition costs of upper-stream enterprises was explained qualitatively in the section of uncertainty analysis, instead of quantitative estimation.

The social costs of phasing out mercury-added products indicate the incremental cost to customers and the state related to the sale and use of mercury free alternative products. For the consumers, the incremental cost includes the increased cost of use and the reduced medical cost, while for the state, the cost includes the increased management cost, the increased financial subsidy for poor population and regions, the reduced waste disposal cost, etc., in which the increase of use cost can be estimated quantitatively by calculating the price change and the cost change of maintenance and calibration, the management cost can be estimated quantitatively by calculating the fund input to enacting regulations and management capacity building, but other increased or decreased social costs are difficult to be quantified and only qualitative analysis is possible. Table 4-1 shows the composition of quantifiable economic cost of enterprises' transformation and social cost.

Table 4-1 Transformation costs of mercury thermometer and manometer to mercury free products

Economic cost of enterprise for phasing out mercury-added products	1. Incremental cost of phasing out mercury-added products production (+)	1-1 enterprises' profit loss
		1-2 losses of wages and benefits and capacity building cost
	2.Incremental cost of producing mercury free products (+)	2-1 technology introduction cost
		2-2 Investment in alternative equipment and infrastructure construction cost
	3. Incremental cost of mercury products and equipment treatment (+)	
	4.Cost of environmental remediation (+)	
	5.Regulatory compliance cost (-)	5-1 environmental management cost
		5-2 mercury-containing waste treatment cost
Social cost of phasing out mercury-added products	6.Incremental cost paid by government (+)	6-1 cost of regulation formulation
		6-2 cost of supervision and administration
	7.Incremental cost paid by consumers (+)	7-1 incremental purchase cost by buying alternatives
		7-2 incremental service cost by using alternatives

Note: (+) indicating cost increase after transition; (-) indicating cost reduction after transition.

In the process of mercury free transition, the phasing-out of mercury thermometer and manometer production will result in profit loss of the manufacturing enterprises, and unemployment of workers who will need compensation of wages and benefits losses and re-employment training. The increased costs of enterprises due to phasing out mercury-added products production constitute the incremental cost of phasing out mercury-added products production.

When implementing the transition to mercury free products production, some enterprises will need to conduct technological R & D or technological introduction because of no ready technology for alternative products production, and need to construct new production line to replace the old one due to the completely different technology between mercury-added products production and mercury free products production, thus requiring modifying and building infrastructure, and purchasing new equipment. The increased costs due to enterprises' transition to producing mercury free products constitute the incremental cost of producing mercury free alternative products.

After enterprises' mercury free transformation, there may be a certain amount of finished or semi-finished product inventory, production equipment, the original facilities used for treating waste water, gas and residue, and mercury-containing waste that require the one-time treatment and disposal, thus increasing the cost of mercury products and equipment treatment. The contaminated sites in mercury-added products manufacturing workshops, waste water treatment site, and mercury recovery workshop need to be treated, that will increase the economic cost of the transition.

In addition, in estimating the incremental economic cost of enterprises' transformation, the saved cost resulted from the transition has to be taken into account, i.e. the regulatory compliance cost of enterprises for meeting national environmental and medical standards. Without considering the basic environmental management cost, the compliance cost in the economic costs of enterprises' transition should include environmental management costs related to mercury pollution control and the treatment cost of mercury pollutants. The environmental management costs are incurred by environmental monitoring, regular medical examination for workers, training of workers, and data reporting; and the treatment cost of mercury pollutants is mainly resulted from the purchase and operation of environmental protection facilities.

The transition to mercury free thermometer and sphygmomanometer will also result in the change of social cost. It is necessary for the government to make study of and develop some transformation policies and standards, and conduct training for regulatory departments at all levels. The regulatory departments need to implement the relevant policies and standards, and conduct demonstrative project of medical institutions on the use of mercury free products, thus resulting in the increased cost paid by government. As the price and maintenance/use costs of mercury free alternative products are much higher than that of the mercury thermometer and sphygmomanometer, the consumers need to pay the incremental purchase cost and incremental service cost, which are the main components of the incremental social cost and can be quantified. In addition, the increased financial subsidy by the state for poor population and regions is also a component of the incremental cost. The use of mercury free products can reduce the exposure risks of populations in hospitals, households, and schools to mercury, reduce environmental pollution, and gain great health and environmental benefits.

4.2. Key factors affecting cost estimation

The transition costs have been estimated based on the data from several enterprises and extrapolated to the whole country. Therefore, in developing the estimation method for each transition cost the key factors that affect this cost should be fully taken into account and reasonable assumptions should be established for key affecting factor, so as to conduct quantified estimation. There are many factors that influence the transition costs, of which the regional difference, time frame of phasing-out, and availability of alternative technologies are the key factors.

Regional difference

There are significant regional differences in terms of the level of workers ' wages, leading to different shares of labor costs in the cost of products for companies in different regions, so that the losses of wages and benefits and capacity building cost which are part of incremental costs of phasing out mercury-added products production will vary; Product sales prices with regional differences will affect the estimation of incremental purchase cost by buying alternatives. Therefore, in view of that it is impossible to obtain the data of every individual enterprise, in establishing estimation method, it should be considered to set the necessary assumptions to simplify the calculation.

Time frame for phasing-out

The time frame for phasing out mercury-added products is linked with the period of profit compensation in cost estimation, and has relatively large influence on the results of estimation. Based on the experience of POPs convention, after the entry into force of the convention, Parties may register for exemption of certain period of time for the transition of products. The longer the applied exemption period is the shorter the corresponding cost compensation period will be. In estimating the economic costs, the profit compensation period can be considered to use the total period of the time from suspending operation to setting up the new production lines and the time from starting to produce mercury free products to getting profit normally. In estimating the social costs, it is assumed that the compensation period is 5 years and 3 years and the costs were calculated under these two hypothetical situations, aiming at comparing the difference of transition cost between two different compensation periods.

Availability of alternative technologies

The availability of alternative technologies is another important factor affecting transition cost. If the alternative technology is relatively mature and can be widely applied in the industry, then there is no need to take the cost of technological introduction into account in calculating the economic costs; If the alternative technology is relatively immature and needs further research and development, technology introduction or patent transfer to make it available, the transfer costs will increase. At present, some alternative technologies are not available domestically, and some technologies or patents are owned by individual enterprise, thus making the results of cost estimation different depending specific case.

5. Methods of estimating the transition costs

5.1. Estimation of economic costs for enterprises' transition

5.1.1. Incremental cost of phasing out mercury-added products production

(1-1) Profit loss of manufacturing enterprises

It indicates the profit loss to enterprises due to shutting down the production of mercury-added products, i.e. the accumulated profit loss of the enterprises in the profit compensation period. When phasing out the production of mercury-added products and shifting to the production of mercury free alternatives, the compensation for enterprises should not be stopped until enterprises get profit normally. So the profit compensation period is defined as the total period of the time from suspending operation to setting up the new production lines and the time from starting to produce mercury free products to getting profit normally.

Estimation formulas:

The weighted average compensation rate for enterprises:

$$LP(a) = \sum_{i=1}^{t} \frac{|Q(a)_i - Q(a)_0| \cdot P(a)}{(1+r)^i}$$

In which,

a - mercury thermometer (or mercury sphygmomanometer);

t -profit compensation period, year;

LP (a) - accumulated profit loss in t years, ten thousand dollars;

$Q(a)_i$ - production output in year i, ten thousand pieces or units;

$Q(a)_0$ - production output in the baseline year, ten thousand pieces or units;

P(a) - profit of unit product, ten thousand dollars/ ten thousand pieces or units;

R - discount rate;

i - year.

In which,

P(a) = sales price of unit product- production cost of unit product

Assumptions:

- It is assumed that the production of mercury thermometer could be eliminated once for all because the calibration of thermometer in China is mostly conducted by employing platinum resistance thermometer, no need to use mercury thermometer;
- Some medical institutions need to keep certain amount of mercury sphygmomanometers for calibrating the mercury free products, so it is not possible to phase out mercury sphygmomanometer production completely. It is assumed that 20% of the production capacity needs to be reserved;
- It is assumed that the time from suspending operation to setting up the new production lines is 2 years; Based on the overall consideration, the time from starting to produce mercury free products to getting profit normally may be different for various enterprises, and the failure to develop the mercury free products' market may bring the potential risk of unsuccessful transition, and this period is assumed to be 5 years;
- It is assumed that the market demand for products be constant, i.e. the annual production output be constant, within the compensation period;
- It is assumed that, within the compensation period, the unit profit P(a) be constant, without taking such factors as price increase and cost fluctuation into account.

Based on the above-mentioned assumptions, the formula for calculating the profit loss of mercury thermometer enterprises can be simplified as follows:

$$LP(a)=\sum_{t=1}^{5}\frac{|Q(a)_0|\cdot P(a)}{(1+r)^t}$$

Calculation parameters:

- Baseline year - 2010;
- The profit compensation period coincides with the total period of the time

from suspending operation to setting up the new production lines and the time from starting to produce mercury free products to getting profit normally, and that is 2+5=7 years;

- Unit product profit, using the average value of the industry;
- The average discount rate - 2.79% (CIA statistics, as of December 31, 2009 the average discount rate of the People's Bank of China).

(1-2) Losses of wages and benefits and capacity building cost

The production technology and process of mercury free products are different from that of producing mercury-added products. Therefore workers with their previous production skill could not meet the requirements for mercury free product production, thus needing re-employment training for them. The anticipated compensation paid for all employees' wages and benefits losses could be used for the relevant capacity building.

Based on the investigation data on the number of workers and the average level of wages in mercy-containing products manufacturing enterprises and considering sales incomes of enterprises, the average share of labor cost in sales income is calculated, and being extrapolated to the whole sector, Then the losses of wages and benefits and capability building cost in the whole country are estimated.

Calculation formulas:

Losses of wages and benefits and capacity building cost= (average share of labor cost in sales income) × (national sales income) × (years of compensation)

In which,

$$(\text{share of labor cost}) = \frac{(\text{number of workers}) \times (\text{average wage})}{(\text{sales income})}$$

sales income = (sale price of unit product) × (annual output)

Assumptions:

- All workers in the mercury-added products manufacturing enterprises were off their working posts and went on reemployment training;
- Sales volume is equal to annual output.

Calculation parameters:

- Number of years of wage compensation is two years (based on POPs practice);
- Wage and benefit compensation is based on the local average level of wages;
- The share of labor cost is calculated by using the average value of the

industry;

- Sales volume is equal to the annual output in 2010.

5.1.2. Incremental cost of producing mercury free alternatives

(2-1) Technology introduction cost

There is no available mature technology for the production of electronic thermometer and sphygmomanometer in mainland China. Having no their own manufacturing technology, enterprises of mainland China have to purchase electronic chips from Germany, Japan, and China Taiwan. Therefore, the full transition will need technology introduction or R & D.

At present, there are few enterprises that possess the patented technology on galinstan thermometer production. In the transition process, it is necessary to consider the technology transfer fee between enterprises, thus giving economic compensation to those enterprises who own the patented technology.

In the case of aneroid sphygmomanometer production in China, things are a little different in that some enterprises have been in production on large scale and exported their products, without the issue of technology transfer; whereas some enterprises are still needing technology introduction or patent transfer, so as to facilitate the full mercury free transition of domestic enterprises.

The data of investigated enterprises is used in estimating the cost.

(2-2) Investment in alternative equipment and infrastructure construction cost

The production technology and process of mercury free alternative products are different from that of producing mercury-added products, therefore it is imperative to modify and build the infrastructure, purchase new equipment.

Calculation formula:

Investment in alternative equipment and infrastructure construction cost = (Investment in alternative equipment and infrastructure construction cost of unit product) × (national annual production capacity)

Assumption:

- There is a linear relationship between the cost and the production capacity of enterprises;
- The annual production capacity of mercury free alternatives is equal to that of mercury-added products.

Estimation parameter:

- Investment in alternative equipment and infrastructure construction cost of unit product is obtained by using the average value of the industry.

5.1.3. Incremental cost of mercury products and equipment treatment

Every product has its own production cycle of certain period of time, for example, 30-40 days for the mercury thermometer, and relatively short time for mercury sphygmomanometer. When the production and sale of mercury-added products were prohibited, there would be some in-stock and semi-finished products needing treatment by enterprises. In addition, the production equipment and the original facilities having been in use for treating waste water, waste gas and waste residue for a very long time need to be scrapped once for all in the environmentally sound manner. Furthermore, all the mercury-containing wastes resulting from transition need to be moved to the qualified companies for treatment and disposal once for all.

Estimation formula:

Incremental cost of mercury products and equipment treatment = (incremental cost of unit product) × (national annual production capacity)

Assumptions:

- The production and use of mercury-added products will be prohibited as soon as the Convention comes into effect;
- The cost of mercury products and equipment treatment is related to the scale of enterprises' production and has a linear relationship with the production capacity;
- The regional difference in treatment cost is ignored.

Estimation parameter:

- The incremental cost of unit product is obtained by using the average value of the industry.

5.1.4. Cost for environmental remediation

After the old production equipment has been dismantled, the sites contaminated by mercury, mainly the production workshops and surrounding area that may be contaminated by mercury, should be cleaned up and remedied. In the case of mercury thermometer and sphygmomanometer production, mercury-added products production workshops, waste water treatment site, mercury recovery workshop and other exposed soil that is not solidified should be the key sites of remedy.

According to the relevant references and information, at present, the cost of environment remediation was estimated by reference to the U.S. thermal desorption process. However, it should practically depend on the remediation technique used domestically in the baseline year. The total cost of mercury thermal desorption system includes cost, operating and maintenance costs, environmental monitoring cost, waste treatment cost, transportation cost, etc. The remediation cost of unit volume soil is USD 834/m^3.

Estimation formula:

Cost for environmental remediation = (unit product environmental remediation cost) × (national annual production capacity)

In which,

unit product environmental remediation cost = [(unit volume soil remediation cost) × (area of the factory) ×10%× (remediation depth)]/(annual production capacity of the enterprise)

Assumptions:

- The environmental remediation cost is related to enterprise's production scale, and has a linear relationship with production capacity;
- The area of contaminated sites is the sum of exposed land areas that is not solidified, accounting for about 10% of the total area of the factory;
- The degree of contamination varies from enterprise to enterprise, needing different remedy depth. It is assumed that the remediation depth be 1 m.
- The regional difference in environmental remediation cost is ignored.

Estimation parameter:

- The unit product environmental remediation cost is obtained by using the average value of the industry.

5.1.5. Regulatory compliance cost

When producing mercury free products, the enterprises, though having some basic compliance costs for meeting national environmental and health policies and standards, will save the compliance cost related to mercury pollution prevention and control, including relevant environmental management cost and mercury-containing waste treatment cost.

(5-1) Environmental management cost

The environmental management cost mainly consists of those economic costs incurred by environmental monitoring, regular health check of workers, training of workers, data reporting, etc.

(5-2) Mercury-containing waste treatment cost

The pollutant treatment cost mainly includes the economic costs for purchasing environmental protection facilities and their operation, and for the routine treatment and disposal of mercury-containing wastes resulting from the regular production of mercury-added products.

Estimation formula:

Regulatory compliance cost = (regulatory compliance cost of unit product) × (national annual production capacity)

In which,

Regulatory compliance cost of unit product = regulatory compliance cost of the investigated enterprises/ annual production capacity of the enterprise

Assumption:

- The regulatory compliance cost is related to the production scale of enterprises, and has a linear relationship with production capacity

Estimation parameter:

- ➢ The regulatory compliance cost of unit product is set by using the average value of the industry.

5.2. Estimation of social cost

5.2.1. Incremental cost paid by government

(6-1) Cost of regulation formulation

The state needs to study, develop or revise policies, laws and regulations, and standards related to substituting mercury free alternatives for mercury thermometer and mercury sphygmomanometer, including enterprise transition policy, license system for mercury free alternatives production, quality standards of mercury free products, medical diagnosis standard, etc. The cost is estimated based on the fund requirement for policy study and development in China.

(6-2) Cost of supervision and administration

The development and implementation/enforcement of policies, laws and regulations, and standards require training the relevant regulatory departments at all levels, thus clearly identifying the responsibility division. The major purpose of the training is to facilitate the implementation and enforcement of policies, laws and regulations, especially the supervision and management over enterprises in transition, so as to ensure the close-down of mercury thermometer and sphygmomanometer manufacturing enterprise according to the time frame and ensure that the in-stock products, mercury-containing wastes, and the contaminated sites are properly treated, disposed, and remedied by the closed enterprises. The training should be conducted in phases, at different levels, and be targets specific. The regulatory departments need to conduct demonstrative projects of medical institutions on the use of mercury free products.

The cost is estimated based on the domestic average charge.

5.2.2. Incremental cost paid by consumers

(7-1) Incremental purchase cost by buying alternatives

The price of mercury free alternatives is higher than that of corresponding mercury-added products, and the consumers need to pay for the incremental purchase cost.

Estimation formula:

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation)

Assumptions:

- The variation of customer's purchasing cost and product transportation cost are reflected in market price;
- The regional difference in product price is ignored;
- The annual output of mercury free alternative products and the export proportion are the same as that of mercury-added products;
- The market demand, the annual output of mercury free alternative products and the export proportion are constant.

Estimation parameters:

- The product price is set based on the average value of the industry;
- The amount of alternative product for the substitution is the domestic sales volume of mercury free alternative products, i.e. the domestic sales volume of mercury–containing products;
- Two hypothetical situations are suggested:
  situation I: 5-year compensation period;
  situation II: 3-year compensation period.

(7-2) Incremental service cost by using alternatives

The way of use and maintenance cost of mercury free products are different from that of mercury-added products, and the consumers need to pay the incremental service cost. The cost includes the calibration cost and cost for batteries.

The mercury thermometer, galinstan thermometer, and electronic thermometer don not need calibration for their whole service life; however, the electronic thermometer needs to use and replace batteries; mercury sphygmomanometer, electronic sphygmomanometer, and aneroid sphygmomanometer need regular calibration, and the electronic sphygmomanometer needs the use and replace of batteries.

Estimation formula:

Incremental service cost = (calibration cost) + (battery cost)

In which,

Calibration cost = (average annual calibration cost of unit alternative product - average annual calibration cost of unit mercury product) × (amount of alternatives) × (years of compensation)

Battery cost = (unit product average annual cost for battery replacement) × (amount of alternatives) × (years of compensation)

The way of defining the amount of alternative product for the substitution and the years of compensation are the same as that for the estimation of incremental purchase cost.

6. Cost estimation of mercury free transition of mercury thermometer

6.1. Basic data employed in the estimation

The Cost of mercury free transition of mercury thermometer includes the economic cost of enterprises' transition and social cost. The economic cost of enterprises' transition has been estimated according two transition scenarios – transforming to galinstan thermometer and to electronic thermometer; the estimation of social cost has been conducted for two hypothetical situations with two transition scenarios in each. In the results of cost estimation, the exchange rate between U.S dollar and RMB is 1 U.S. dollar = 6.3 RMB yuan.

Table 6-1 and 6-2 show the basic data used in estimating transition cost.

Table 6-1 Basic data on mercury thermometer for analysis model of transition cost

Parameters	Value
Production capacity (10 thousand thermometers)	18300
Production output (10 thousand thermometers)	15000
Sale price of unit product (dollar)	0.27
Unit product profit (dollar)	0.051
Average service life of product (year)	-
Average share of labor cost in sales income (%)	20.25
Mercury products and equipment treatment cost of unit product (10 thousand dollars /10 thousand thermometers)	0.032
Environmental remediation cost of unit product (dollar/10 thousand thermometers)	445.34
Regulatory compliance cost of unit product (10 thousand dollars /10 thousand thermometers)	0.0063

Table 6-2 Basic data on mercury free thermometers for analysis model of transition cost

Parameters	Galinstan Thermometer	Electronic Thermometer
Production capacity (10 thousand thermometers)	18300	18300
Production output (10 thousand thermometers)	15000	15000
Technology introduction or patent transferred cost (10 thousand dollars)	269.84	79.37
Investment in alternative equipment and infrastructure construction cost of unit product (10 thousand dollars /10 thousand thermometers)	1	0.92
Sale price of unit product (dollar)	1.96	1.41
Average service life of product (year)	-	4
Calibration cost (dollar/year)	-	-
Payback period (year)	8	10

6.2. Estimation of economic cost for the transition of mercury thermometer producing enterprises

6.2.1. Incremental cost of phasing out mercury thermometer production

(1-1) Profit loss of mercury thermometer producing enterprise

The accumulated profit loss of the enterprise when making full transition to producing mercury free thermometer is

$$LP(a) = \sum_{i=1}^{t} \frac{|Q(a)_e| \cdot P(a)}{(1+r)^i} = \sum_{i=1}^{7} \frac{15000 \times 0.051}{(1+2.79\%)^i} = 4804.12 \text{ (ten thousand dollars)}$$

In which,

- The profit compensation period (t) is 7 years.
- The baseline year output of mercury thermometer $Q(a)_0$ = 15000 (ten thousand pieces)
- Unit product profit P(a) = (sale price of unit product) – (production cost of unit product) = 0.32 yuan ≈ $0.051

(1-2) Losses of wages and benefits and capacity building cost

Losses of wages and benefits and capacity building cost= (average share of labor cost in sales income) × (national sales income) × (years of compensation)

= 20.25% × 4050 × 2 = 1640.25 (ten thousand dollars)

In which,

- The percentage of labor cost nationwide is about 20.25%.
- The sales income nationwide = (sales price of unit product) × (annual output nationwide) = 0.27×15000 = 4050 (ten thousand dollars)

  The annual output of mercury thermometer of China is 150,000,000. The sales price of unit product is about 1.7 yuan ≈ $0.27
- The compensation period is two years.

6.2.2. Incremental cost of producing mercury free thermometer

(2-1) technology introduction cost

Scenario 1: galinstan thermometer

It is known through survey that there are two domestic companies possessing the galinstan thermometer technology on which technology transfer can be made. The technology transfer cost is about 1700 (ten thousand yuan) ≈ 269.84 (ten thousand dollars)

Scenario 2: electronic thermometer

There is no domestically owned technology for the manufacture of electronic thermometer chips in mainland China, thus requiring either technology introduction from abroad or independent R & D. In view of the uncertainty of technology introduction from abroad, only the independent R & D by domestic enterprises is considered. Based on the survey data, the cost of independent R & D is about 500 (ten thousand yuan) ≈79.37 (ten thousand dollars)

(2-2) Investment in alternative equipment and infrastructure construction cost

Scenario 1: galinstan thermometer

Investment in alternative equipment and infrastructure construction cost = (Investment in alternative equipment and infrastructure construction cost of unit product) × (national annual production capacity) = 1 × 18300 = 18300 (ten thousand dollars)

In which,

- The national annual production capacity of mercury thermometer is 18300 (ten thousand).
- The investment in alternative equipment and infrastructure construction cost of unit product is about 6.33 (ten thousand yuan)/(ten thousand thermometers) ≈1 (ten thousand dollars)/(ten thousand thermometers)

Scenario 2: electronic thermometer

Investment in alternative equipment and infrastructure construction cost = (Investment in alternative equipment and infrastructure construction cost of unit product) × (national annual output) = 0.92 × 18300 = 16836 (ten thousand dollars)

In which,

- The national annual production capacity of mercury thermometer is 18300 (ten thousand).
- The investment in alternative equipment and infrastructure construction cost of unit product is about 5.78 (ten thousand yuan)/(ten thousand thermometers) ≈ 0.92(ten thousand dollars)/(ten thousand thermometers).

6.2.3. Incremental cost of mercury products and equipment treatment

Incremental cost of mercury products and equipment treatment = (incremental cost of unit product) × (national annual production capacity)

= 0.032×18300= 585.6 (ten thousand dollars)

In which,

- The national annual production capacity of mercury thermometer is 18300 (ten thousand).
- The incremental cost of unit product is about 0.20(ten thousand yuan)/(ten thousand thermo.) ≈ 0.032(ten thousand dollars)/(ten thousand thermo.)

6.2.4. Cost of environmental remediation

Cost for environmental remediation = (unit product environmental remediation cost) × (national annual production capacity)

= 445.34×18300=814.97(ten thousand dollars)

In which,

- The national annual production capacity of mercury thermometer is 18300 (ten thousand).
- The unit product environmental remediation cost is about \$445.34/(ten thousand thermometers). The calculation formula is as follows:

  unit product environmental remediation cost = [(unit volume soil remediation cost) × (area of the factory) ×10%× (remediation depth)]/(annual production capacity of the enterprise)

  In which, the unit volume soil remediation cost is about \$ 834/m^3, and the remediation depth of 1 meter.

6.2.5. Regulatory compliance cost

Regulatory compliance cost = (unit product regulatory compliance cost) × (national annual production capacity)

= 0.0063×18300 = 115.29 (ten thousand dollars)

In which,

- The national annual production capacity of mercury thermometer is 18300 (ten thousand).
- The unit product regulatory compliance cost is about 0.04 (ten thousand yuan)/(ten thousand thermometers) ≈ 0.0063 (ten thousand dollars)/(ten thousand thermometers)

6.3. Estimation of social cost for the mercury free transition of mercury thermometer

6.3.1. Incremental cost paid by government

(6-1) Cost of regulation formulation

Based on the fund requirement for policy study and development in China, it is estimated that 3 million yuan (about 476,200 dollars) will be needed to develop enterprise transition policy, license system for mercury free alternatives production, quality standards of mercury free products, medical diagnosis standard, etc.

(6-2) Cost of supervision and administration

To facilitate the implementation of national policies, laws and regulations, and standards, and to supervise the mercury free transition of enterprises, it is necessary to conduct 3 national trainings for provincial regulatory departments, and 7 trainings by seven key provinces (municipalities directly under the central government) for regulatory departments within their jurisdiction, where most domestic mercury thermometer producing enterprises are located on. The cost of one training is about 20 ten thousand yuan. The total cost for 10 trainings is: 10×20 = 200 ten thousand yuan ≈31.75 ten thousand dollars.

The local regulatory departments should implement the pilot projects on the use of mercury free products in medical institutions. The medical institutions are distributed throughout 31 provinces (municipalities directly under the central government), in each of which 2 medical institutions are selected to conduct the pilot project. The cost for each institution is about 20 ten thousand yuan. Thus the total cost is: 31×2×20 = 1240 ten thousand yuan ≈196.83 ten thousand dollars.

The total cost of supervision and administration is about 31.75+196.83=228.58 ten thousand dollars.

6.3.2. Incremental cost paid by consumers

(7-1) Incremental purchase cost by buying alternatives

Scenario 1: galinstan thermometer

Situation I: compensation period of five years

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (1.96-0.27) ×7500×5=63375 (ten thousand dollars).

In which,

- The amount of substitution by the alternative product = domestic sales volume = annual output of mercury thermometer × (1- export proportion), =15000 × 50% = 7500 (ten thousand thermometers)
  The annual output of mercury free alternative products, same as mercury-added products, is 15000, and the export proportion of mercury free products, same as mercury-added products, is about 50%;
- The price of unit alternative product is about 12.37 yuan ≈ \$1.96. The price of mercury-added product is about 1.71 yuan ≈ \$0.27

Situation II: compensation period of three years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (1.96-0.27) ×7500×3=38025 (ten thousand dollars).

Scenario 2: electronic thermometer

Situation I: compensation period of five years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (1.41-0.27) ×7500×5=42750(ten thousand dollars).

In which,

- The amount of substitution by the alternative product = domestic sales volume = annual output of mercury thermometer × (1- export proportion), =15000 × 50% = 7500 (ten thousand thermometers)

  The annual output of mercury free alternative products, same as mercury-added products, is 15000, and the export proportion of mercury free products, same as mercury-added products, is about 50%;
- The price of unit alternative product is about 8.87 yuan ≈ \$1.41. The price of unit mercury-added product is about \$0.27.

Situation II: compensation period of three years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (1.41-0.27) ×7500×3=25650(ten thousand dollars).

(7-2) Incremental service cost by using alternatives

Scenario 1: galinstan thermometer

There is no need for mercury thermometer and galinstan thermometer to be calibrated when in use, and no need to use battery. Therefore the incremental service cost is zero.

Scenario 2: electronic thermometer

Situation I: compensation period of five years.

Incremental service cost = (calibration cost) + (battery cost)

= 0 + 2250= 2250 (ten thousand dollars).

In which,

- Calibration cost: There is no need for mercury thermometer and electronic thermometer to be calibrated when in use. Therefore the maintenance cost of electronic thermometer is zero.
- Battery cost = (unit product average annual cost for battery replacement) × (amount of alternatives) × (years of compensation)

  = 0.06 × 7500 × 5 = 2250 (ten thousand dollars)
- The service life of electronic thermometer is about 4 years. One electronic thermometer uses one button battery with price of 1.5 yuan and needs only

one replacement of battery in its service life of 4 years. Thus, the annual battery cost of one electronic thermometer is 1.5/4 = 0.375yuan ≈ \$0.06.

The amount of substitution by the alternative product = domestic sales volume = annual output of mercury thermometer × (1- export proportion), =15000 × 50% = 7500 (ten thousand thermometers)

Situation 2: compensation period of three years.

Incremental service cost = (calibration cost) + (battery cost)

= 0 + 1350 = 1350 (ten thousand dollars).

In which,

- Calibration cost = 0
- Battery cost = 0.06 × 7500 × 3 = 1350 (ten thousand dollars)

6.4. Summery and analysis on transition cost

6.4.1. Analysis on economic cost for the transition of mercury thermometer producing enterprises

The economic cost of thermometer's mercury free transition varies depending on transition scenarios. The economic cost of transition to galinstan thermometer is higher than electronic thermometer (see Table 6-3). The total cost of transition to scenario1 is higher than transition to scenario 2 because the former needs more input in R & D and investment in production equipment and infrastructure construction cost than the latter.

Table 6-3 Economic cost of thermometer's mercury free transition

Type of cost		Scenario 1: galinstan thermometer	Percentage of cost (%)	Scenario 2: electronic thermometer	Percentage of cost (%)
1. Incremental cost of phasing out mercury thermometer production (ten thousand dollars)					
1-1	Enterprises' profit loss	4804.12	18.3	4804.12	19.5
1-2	Losses of wages and benefits and capacity building cost	1640.25	6.2	1640.25	6.7
Sub-total		6444.37	24.5	6444.37	26.1
2、Incremental cost of producing mercury free products (ten thousand dollars)					
2-1	Technology introduction cost	269.84	1.0	79.37	0.3
2-2	Investment in alternative equipment and infrastructure construction cost	18300	69.6	16836	68.3
Sub-total		18569.84	70.6	16915.37	68.6
3、Incremental cost of mercury products and equipment treatment (ten thousand dollars)					
3-1	Incremental treatment cost	585.6	2.2	585.6	2.4
4、Cost of environmental remediation (ten thousand dollars)					
4-1	Environmental remediation cost	814.97	3.1	814.97	3.3
5、Regulatory compliance cost (ten thousand dollars)					
5-1	Environmental management cost	-115.29	-0.4	-115.29	-0.5
5-2	Mercury-containing waste treatment cost				
Sub-total		-115.29	-0.4	-115.29	-0.5
Total		26299.49	100	24645.02	100

Note: the negative mark "-" indicates the saved cost through transition.

In the two scenarios, the percentage of incremental cost of producing mercury free thermometer is the highest, accounting for about 71%, in which the cost of investment in alternative equipment and infrastructure construction accounts for as high as 70%; The percentage of incremental cost for phasing out mercury thermometer production is the second highest, accounting for 25%, in which enterprise's profit loss accounts for the largest share (about 18%), and other costs have relatively small share.

6.4.2 Analysis on social cost

The medical device industry related to people's health and livelihood, having prominent social value and can't be simply measured by economic indicators. Therefore, attention should also be paid to the social cost of its mercury free transition. Table 6-4 shows the estimation result of incremental social costs paid by government and consumers.

In the same transition scenario, the social cost of hypothetical situation I with compensation period of 5 years long is 66% higher than that of situation II where the compensation period is 3 years. In the same situation, the total social cost of transition to electronic thermometer is lower than that of transition to galinstan thermometer.

In the two transition scenarios, the incremental costs paid by government are the same, but the incremental cost paid by consumers of galinstan thermometer is higher than electronic thermometer. If the former is chosen, the customers will have to bear higher incremental purchase cost. The price of metal tin, the raw material for making galinstan thermometer is increasing year by year and the domestic reserve of tin ore is decreasing year by year. These may increase the incremental purchase cost. If the electronic thermometer is chosen, users will not only bear the incremental purchase cost but also the incremental service cost.

Table 6-4 Social cost for the transition to mercury free thermometer

Type of cost		Situation I				Situation II			
		Galinstan thermometer	%	electronic thermometer	%	Galinstan thermometer	%	electronic thermometer	%
6、Incremental cost paid by government (ten thousand dollars)									
6-1	Cost of regulation formulation	47.62	0.1	47.62	0.1	47.62	0.1	47.62	0.2
6-2	Cost of supervision and administration	228.58	0.4	228.58	0.5	228.58	0.6	228.58	0.8
Sub-total		276.2	0.4	276.2	0.6	276.2	0.7	276.2	1.0
7、Incremental cost paid by consumers (ten thousand dollars)									
7-1	Incremental purchase cost	63375	99.6	42750	94.4	38025	99.3	25650	94.0
7-2	Incremental service cost	0	0	2250	5.0	0	0	1350	4.9
Sub-total		63375	99.6	45000	99.4	38025	99.3	27000	99.0
Total		63651.2	100	45276.2	100	38301.2	100	27276.2	100

In addition to the increased social cost, the health benefit and environmental benefit are also the important components of social cost. The mercury free transition could reduce the demand for mercury, thus correspondingly resulting in the reduction of mercury-containing wastes generated and discharges from mercury mining and smelting, thus having certain environmental benefit. Mercury thermometer is very easy to break in the process of use due to improper operation, resulting in mercury exposure that may bring about risk to human health and environment if not properly dealt with. The mercury free transition would not only phase out the mercury related production process, thus protecting worker's health, but also protect more customers to some extent from risking mercury exposure, having certain health benefit. On the contrary, the use of mercury free alternatives could increase the training cost of medical institutions for using new products, and increase the burden of government aiding poverty-stricken areas, which are also the important component of social costs, though they are not estimated quantitatively in the report. It is assumed that the benefit and cost that were not quantified in the report could be canceled out one another, and they are not included in the incremental costs.

7. Cost estimation of mercury free transition of mercury sphygmomanometer

7.1. Basic data employed in the estimation

The Cost of mercury free transition of mercury sphygmomanometer includes the economic cost of enterprises' transition and social cost. The economic cost of enterprises' transition has been estimated according two transition scenarios – transforming to electronic sphygmomanometer and aneroid sphygmomanometer; the estimation of social cost has been conducted for two hypothetical situations with two transition scenarios in each. In the results of cost estimation, the exchange rate between U.S dollar and RMB is 1 U.S. dollar = 6.3 RMB yuan.

Table 7-1 and 7-2 show the basic data used in estimating transition cost.

Table 7-1 Basic data on mercury sphygmomanometer for analysis model of transition cost

Parameters	Value
Production capacity (10 thousand)	418
Production output (10 thousand)	325
Sale price of unit product (dollar)	7.85
Unit product profit (dollar)	1.98
Average service life of product (year)	5
Average share of labor cost in sales income (%)	15.88
Mercury products and equipment treatment cost of unit product (10 thousand dollars /10 thousand manometers)	0.70
Environmental remediation cost of unit product (dollar/10 thousand sphygmomanometers)	2181.66
Regulatory compliance cost of unit product (10 thousand dollars /10 thousand sphygmomanometers)	0.09
Production capacity (10 thousand)	4.13

Table 7-2 Basic data on mercury free sphygmomanometers for analysis model of transition cost

Parameters	Electronic Sphygmomanometer	Aneroid Sphygmomanometer
Production capacity (10 thousand)	334.4	334.4
Production output (10 thousand)	260	260
Technology introduction or patent transferred cost (10 thousand dollars)	71.43	47.62
Investment in alternative equipment and infrastructure construction cost of unit product (10 thousand dollars /10 thousand sphygmomanometers)	0.54	5.29
Sale price of unit product (dollar)	24.24	8.22
Average service life of product (year)	4	3
Calibration cost (dollar/year)	14.29	4.13
Payback period (year)	3	9

7.2. Estimation of economic cost for the transition of mercury Sphygmomanometer producing enterprises

7.2.1. Incremental cost of phasing out mercury sphygmomanometer production

(1-1) Profit loss of mercury sphygmomanometer producing enterprise

The medical institutions as the principal domestic user of mercury sphygmomanometer need to keep certain amount of mercury sphygmomanometers to meet certain particular patients' requirements because the measurement precision of mercury free sphygmomanometer needs to be further improved. So it is not possible to phase out mercury sphygmomanometer production completely. It is assumed that 20% of the production capacity needs to be reserved.

The accumulated profit loss of the enterprise when making full transition to producing mercury free sphygmomanometer is

$$LP(a) = \sum_{i=1}^{t} \frac{|Q(a)_i - Q(a)_0| \cdot P(a)}{(1+r)^i} = \sum_{i=1}^{7} \frac{|65 - 325| \times 1.98}{(1+2.79\%)^i} = 3232.89 \text{(ten thousdan dollars)}$$

In which,

- The profit compensation period (t) is 7 years.
- The baseline year output of mercury sphygmomanometer $Q(a)_0$ = 325 (ten thousand)
- The annual output of mercury sphygmomanometer in year i is $Q(a)_i = 20\%\ Q(a)_0 = 0.2 \times 325 = 65$ (ten thousand)
- Unit product profit = (sale price of unit product) – (production cost of unit product) = 12.47 yuan≈$ 1.98

(1-2) Losses of wages and benefits and capacity building cost

Losses of wages and benefits and capacity building cost= (average share of labor cost in sales income) × (national sales income) × (years of compensation)

= 15.88% × 2551.25 × 2 = 810.28 (ten thousand dollars)

The cost should be deducted by 20% due to 20% of the production capacity of mercury sphygmomanometer has been kept: 810.28 × (1-20%) = 648.22(ten thousand dollars)

In which,

- The percentage of labor cost nationwide is about 15.88%.
- The sales income nationwide = (sales price of unit product) × (annual output nationwide) =7.85×325 = 2551.25(ten thousand dollars)
- The national annual output of mercury sphygmomanometer is 325 (ten thousand pieces) with unit product sales price being 49.47 yuan≈ $7.85.
- The compensation period is 2 years.

7.2.2. Incremental cost of producing mercury free sphygmomanometer

(2-1) technology introduction cost

Scenario 1: electronic sphygmomanometer

The technology of electronic chips for electronic sphygmomanometer is not available in mainland China and need to be introduced from abroad or researched and developed independently. In view of the uncertainty of technology introduction from abroad, only the independent R & D by domestic enterprises is considered. Based on the survey data, the cost of independent R & D is about 450 (ten thousand yuan) ≈ 71.43 (ten thousand dollars)

Scenario 2: aneroid sphygmomanometer

Some domestic enterprises have owned the production technology of aneroid sphygmomanometer and there are no such issues as independent R & D or technology introduction, while some enterprises still require technology transfer. The transfer cost is about 3 million yuan (about 476,200 dollars).

(2-2) Investment in alternative equipment and infrastructure construction cost

Scenario 1: electronic sphygmomanometer

Investment in alternative equipment and infrastructure construction cost = (Investment in alternative equipment and infrastructure construction cost of unit product) × (national annual production capacity) = 0.54 × 334.4= 180.58 (ten thousand dollars)

In which

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved; the national annual production capacity indicates the total capacity that needs to be transformed by the enterprises. That is 418 × (1-20%) = 334. 4 (ten thousand sphygmomanometers).
- The investment in alternative equipment and infrastructure construction cost of unit product is about 3.43(ten thousand yuan)/(ten thousand manometers) ≈ 0.54(ten thousand dollars)/(ten thousand manometers)

Scenario 2: aneroid sphygmomanometer

Investment in alternative equipment and infrastructure construction cost = (Investment in alternative equipment and infrastructure construction cost of unit product) × (national annual output) =5.29 × 334.4= 1768.98 (ten thousand dollars)

In which

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved; the national annual production capacity indicates the total capacity that needs to be transformed by the enterprises. That is 418 × (1-20%) = 334. 4 (ten thousand).

- The investment in alternative equipment and infrastructure construction cost of unit product is about 33.33(ten thousand yuan)/(ten thousand manometers) ≈ 5.29(ten thousand dollars)/(ten thousand manometers)

7.2.3. Incremental cost of mercury products and equipment treatment

Incremental cost of mercury products and equipment treatment = (incremental cost of unit product) × (national annual production capacity)

= 0.70×334.4= 234.08 (ten thousand dollars)

In which,

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved; the national annual production capacity indicates the total capacity that needs to be transformed by the enterprises. That is 418 × (1-20%) = 334. 4 (ten thousand).
- The incremental cost of unit product is about 4.44(ten thousand yuan)/(ten thousand manometers) ≈ 0.70(ten thousand dollars)/(ten thousand manometers)

7.2.4. Cost of environmental remediation

Cost for environmental remediation = (unit product environmental remediation cost) × (national annual production capacity)

= 2181.66×334.4=72.95(ten thousand dollars)

In which,

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved, the national annual production capacity indicates the total capacity that needs to be transformed by the enterprises. That is 418 × (1-20%) = 334. 4 (ten thousand).
- The unit product environmental remediation cost is about $2181.66/(ten thousand manometers). The calculation formula is as follows:
  unit product environmental remediation cost = [(unit volume soil remediation cost) × (area of the factory)×10%× (remediation depth)]/(annual production capacity of the enterprise)
  In which, the unit volume soil remediation cost is about $ 834/m^3, and the remediation depth of 1 meter.

7.2.5. Regulatory compliance cost

Regulatory compliance cost = (unit product regulatory compliance cost) ×

(national annual production capacity) = 0.09×334.4 = 30.1 (ten thousand dollars)

In which,

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved, and the national annual production capacity indicates the total capacity that needs to be transformed by the enterprises. That is 418 × (1-20%) = 334. 4 (ten thousand).
- The unit product regulatory compliance cost is about 0.57 (ten thousand yuan)/(ten thousand manometers) ≈ 0.09 (ten thousand dollars)/(ten thousand manometers)

7.3. Estimation of social cost for the mercury free transition of mercury sphygmomanometer

7.3.1. Incremental cost paid by government

(6-1) Cost of regulation formulation

The cost of regulation formulation is the same as for the case of mercury thermometer, about 3 million yuan or 476,200 dollars.

(6-2) Cost of supervision and administration

To facilitate the implementation of national policies, laws and regulations, and standards, and to supervise the mercury free transition of enterprises, it is necessary to conduct 3 national trainings for provincial regulatory departments, and 2 trainings by key provinces (municipalities directly under the central government) for regulatory departments within their jurisdiction. The cost of one training is about 20 ten thousand yuan. The total cost for 5 trainings is: 5×20 = 100 (ten thousand yuan) ≈ 15.87 (ten thousand dollars).

The regulatory departments should implement the pilot projects on the use of mercury free products in medical institutions. The medical institutions are distributed throughout 31 provinces (municipalities directly under the central government), in each of which 2 medical institutions are selected to conduct the pilot project. The cost for each institution is about 20 ten thousand yuan. Thus the total cost is: 31×2×20 = 1240 ten thousand yuan ≈196.83 ten thousand dollars.

The total cost of supervision and administration is about 15.87+196.83=212.7 ten thousand dollars.

7.3.2. Incremental cost paid by consumers

(7-1) Incremental purchase cost by buying alternatives

Scenario 1: electronic sphygmomanometer

Situation I: compensation period of five years

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (24.24-7.85) ×260×5=21307 (ten thousand dollars).

In which,

- It is assumed that 20% of the mercury sphygmomanometer production capacity will be reserved; as almost all sphygmomanometers are sold domestically, the amount of alternative product indicates the amount of output that needs to be transformed by the enterprises. That is 325 × (1-20%) =260 (ten thousand).
- The price of unit alternative product is about 152.69 yuan ≈ \$24.24. The price of unit mercury-added product is about 49.47 yuan ≈ \$7.85.

Situation II: compensation period of three years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (24.24-7.85) ×260×3=12784.2 (ten thousand dollars).

Scenario 2: aneroid sphygmomanometer

Situation I: compensation period of five years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (8.22-7.85) ×260×5=481(ten thousand dollars).

In which,

- It is assumed that 20% of the mercury sphygmomanometer production capacity will to be reserved; as almost all sphygmomanometers are sold domestically, the amount of alternative product indicates the amount of output that needs to be transformed by the enterprises. That is 325 × (1-20%) =260 (ten thousand).
- The price of unit alternative product is about 51.77 yuan ≈ \$8.22. The price of unit mercury-added product is about \$7.85.

Situation II: compensation period of three years.

Incremental purchase cost = [(price of alternative product) - (price of mercury-added product)] × (amount of alternative product) × (years of compensation) = (8.22-7.85) ×260×3=288.6(ten thousand dollars).

(7-2) Incremental service cost by using alternatives

Scenario 1: electronic sphygmomanometer

Situation I: compensation period of five years

Incremental service cost = (calibration cost) + (battery cost)

= 13208 + 819= 14027 (ten thousand dollars).

In which,

- Calibration cost = (average annual calibration cost of unit alternative product - average annual calibration cost of unit mercury product) × (amount of alternatives) × (years of compensation)

  = (14.29-4.13) × 260 ×5=13208(ten thousand dollars)

  The service life of mercury sphygmomanometer is about 5 years. The service life of electronic manometer is about 4 years. According to the metrological verification charging standard in Beijing, the verification fee of one mercury sphygmomanometer is 13 yuan/(per half year), thus, the average annual calibration fee is 13 ×2 = 26 yuan ≈ $ 4.13; The annual verification fee of one electronic sphygmomanometer is 90 yuan/year, thus the annual calibration cost of one electronic sphygmomanometer is 90 yuan ≈ $ 14.29.

  The substitution amount is 325× (1-20%) = 260 (ten thousand manometers).

- Battery cost = (unit product annual cost for battery replacement) × (substitution amount) × (years of compensation)

  = 0.63 ×260× 5 = 819 (ten thousand dollars).

  One electronic sphygmomanometer uses two AA batteries with unit price of 2 yuan and needs to replace the batteries 4 times in its 4-year service life. Thus, the annual battery cost of one electronic manometer is 2×2×4/4 = 4 yuan ≈ $ 0.63.

  The substitution amount is 325 × (1-20%) = 260 (ten thousand sphygmomanometers).

Situation II: compensation period of three years

Incremental service cost = (calibration cost) + (battery cost)

= 7924.8 +491.4 = 8416.2 (ten thousand dollars).

In which,

- Calibration cost = (14.29-4.13) × 260 ×3 = 7924.8 (ten thousand dollars)
- Battery cost = 0.63 ×260× 3 = 491.4 (ten thousand dollars)

Scenario 2: aneroid sphygmomanometer

Situation I: compensation period of five years

Incremental service cost = (calibration cost) + (battery cost) = 0

In which,

- Calibration cost = (average annual calibration cost of unit alternative product - average annual calibration cost of unit mercury product) × (amount of alternatives) × (years of compensation)

  = (4.13-4.13) × 260.26 × 5 = 0

  The service life of aneroid sphygmomanometer is about 3 years. According to the metrological verification charging standard in Beijing, the verification fee of one aneroid sphygmomanometer is 13 yuan/(per half year), thus, the average annual calibration fee is 13 ×2 = 26 yuan/year ≈ $ 4.13/year; The annual calibration fee of one mercury sphygmomanometer is 26 yuan/year ≈ $ 4.13/year.

  The substitution amount is 325 × (1-20%) = 260 (ten thousand manometers).
- The aneroid sphygmomanometer doesn't need the use of battery, thus the battery cost is zero.

Situation 2：compensation period of three years

Incremental service cost = (calibration cost) + (battery cost) = 0

7.4. Summary and analysis on transition cost

7.4.1 Analysis on economic cost for the transition of mercury sphygmomanometer producing enterprises

The economic cost of manometer's mercury free transition varies depending on transition scenarios. The economic cost of transition to aneroid sphygmomanometer is higher than electronic sphygmomanometer. See Table 7-3 for details.

Table 7-3 Economic cost of sphygmomanometer's mercury free transition

Type of cost		Scenario 1: Electronic Sphygmomanometer	Percentage of cost (%)	Scenario 2: Aneroid Sphygmomanometer	Percentage of cost (%)
1. Incremental cost of phasing out mercury sphygmomanometer production **(ten thousand dollars)**					
1-1	Enterprises' profit loss	3232.89	73.3	3232.89	54.1
1-2	Losses of wages and benefits and capacity building cost	648.22	14.7	648.22	10.8
Sub-total		3881.11	88.0	3881.11	65.0
2、Incremental cost of producing mercury free products (ten thousand dollars)					
2-1	Technology introduction cost	71.43	1.6	47.62	0.8
2-2	Investment in alternative equipment and infrastructure construction cost	180.58	4.1	1768.98	29.6
Sub-total		252.01	5.7	1816.6	30.4
3、Incremental cost of mercury products and equipment treatment (ten thousand dollars)					
3-1	Incremental treatment cost	234.08	5.3	234.08	3.9
4、Cost of environmental remediation (ten thousand dollars)					
4-1	Environmental remediation cost	72.95	1.7	72.95	1.2
5、Regulatory compliance cost (ten thousand dollars)					
5-1	Environmental management cost	-30.1	-0.7	-30.1	-0.5
5-2	Mercury-containing waste treatment cost				
Subtotal		-30.1	-0.7	-30.1	-0.5
Total		4410.05	100	5974.64	100

Note: the negative mark "-" indicates the saved cost through transition

The investment in alternative equipment and infrastructure construction cost for the transition to aneroid sphygmomanometer production is much higher than that of transition to electronic sphygmomanometer production, leading to a higher incremental cost of production and higher total transition cost.

In the transition to electronic sphygmomanometer, the incremental cost of phasing out mercury sphygmomanometer production has the highest share of cost, accounting for about 88%, in which enterprise's profit loss accounts for 73%; other costs only accounting for a relatively small percentage. In the transition to aneroid sphygmomanometer, the incremental cost of phasing out mercury manometer production accounts for 65%, in which enterprise's profit loss has the largest share of about 54%; the incremental cost of mercury free sphygmomanometer production is at the second place, accounting for about 30%; other costs only accounting for a relatively small percentage.

7.4.2 Analysis on social cost

In the social cost of mercury free sphygmomanometer transition, the incremental costs paid by government in the two scenarios are the same. There is no incremental service cost for the transition to aneroid sphygmomanometer, and the incremental purchase cost and incremental service cost for the transition to electronic sphygmomanometer are higher than aneroid sphygmomanometer. Table 7-4 shows the estimation results.

Table 7-4 Social cost for the transition to mercury free sphygmomanometer

Type of cost		**Situation I**				**Situation II**			
		Electronic sphygmomanometer	%	Aneroid Sphygmomanometer	%	Electronic sphygmomanometer	%	Aneroid sphygmomanometer	%
6、Incremental cost paid by government (ten thousand dollars)									
6-1	Cost of regulation formulation	47.62	0.1	47.62	6.4	47.62	0.2	47.62	8.7
6-2	Cost of supervision and administration	212.7	0.6	212.7	28.7	212.7	1.0	212.7	38.7
Sub-total		260.32	0.7	260.32	35.1	260.32	1.2	260.32	47.4
7、Incremental cost paid by consumers (ten thousand dollars)									
7-1	Incremental purchase cost	21307	59.9	481	64.9	12784.2	59.6	288.6	52.6
7-2	Incremental service cost	14027	39.4	0	0	8416.2	39.2	0	0
Sub-total		35334	99.3	481	64.9	21200.4	98.8	288.6	52.6
Total		35594.32	100	741.32	100	21460.72	100	548.92	100

In addition to the quantifiable social cost, the mercury free transition of sphygmomanometer could produce certain health and environmental benefits thus cutting down the social costs. At the same time, the training cost of the use of mercury free alternatives in medical institutions and the increased burden of government in aiding poverty-stricken areas could increase the social costs. It is assumed that the benefit and cost that were not quantified in the report could be canceled out one another, and they are not included in the incremental costs.

8. Analysis on the uncertainty of cost estimation

In the estimation of the economic and social costs of the mercury free transition of mercury thermometer and mercury sphygmomanometer, some necessary assumptions have been suggested in order to avoid unquantifiable factors and simplify the estimation methods, thus increasing the uncertainty of the cost estimation. The economic development factors, estimation method, and value method have relatively large impact on the results of estimation.

8.1 Economic development factors

Though the impact of economic development on the production capacity and output of product, wage level of workers and labor cost, and product price is inevitable, it has been basically ignored in the estimation of transition cost.

In this report, the estimation of several types of cost has been based on 2010 production capacity and output of mercury thermometer and mercury sphygmomanometer, without considering the possible change in the coming years. In fact, the production capacity and output of mercury thermometer and mercury sphygmomanometer has been increasing in China in recent years, and this trend will definitely continue in the coming years with the rapid economic growth. Therefore, every transition cost being estimated based on production capacity and output would inevitably increase.

In view of China’s current economic development trend, the average level of worker’s wage and labor cost will increase substantially in the coming years, thus increasing the wage and benefit compensation cost and capacity building cost which account for a relatively high percentage of the total cost and have relatively large impact on the total cost. The increase of labor cost would also increase the incremental cost of phasing out mercury-added product production to a certain extent.

The impact of economic development on product price has relatively large uncertainty, which may increase or decrease, thus having impact on the social cost estimated based on product price. However, the impact of product price change on the uncertainty of estimation results would decrease due to the price difference between mercury-added product and mercury free product being considered in the estimation.

8.2 Estimation method

In estimating the economic cost of enterprise for phasing out mercury-added product, only the economic cost of mercury thermometer and mercury sphygmomanometer producing enterprises in transition was considered without taking into account the economic cost for the transition of the upper-stream mercury producing and processing enterprises, thus making the estimated incremental cost lower than the actual cost.

In estimating the social cost of phasing out mercury-added product, the cost of training customers on the use of mercury free product was ignored, thus making the estimation of this cost lower than the actual cost.

In the estimation, the extrapolation has been used to get the average value of the industry based on the data obtained from several enterprises being surveyed due to the unavailability of data from every individual enterprise. Therefore, the estimation results are of uncertainty.

8.3 Value getting method

Due to the lack of basic data required in the estimation, it is necessary to define a rational value getting method based on certain assumptions to get required unknown data through known data. The impact of value getting method on the cost estimation varies depending on the types of cost.

There is little error in cost estimation when using the annual production output as the annual sales volume, because there is little difference between enterprise's annual production output and annual sales volume in reality. In the estimation of investment in alternative equipment and infrastructure construction cost, mercury products and equipment treatment cost, regulatory compliance cost, and environmental remediation cost, it is assumed that there is a linear relationship between cost and production capacity because these incremental costs are associated with the size of enterprise. However, the actual situation could not strictly follow the linear relationship, thus this assumption having impact on the accuracy of the estimation results. In the estimation of environmental remediation cost, the depth of soil to be treated was set at one meter, which may not be appropriate for the actual situation due to the different level of soil contamination in different enterprises. In some heavily contaminated sites, remediation for deeper soil may be needed and the remediation cost may be higher than the estimated cost in the report.

9. Discussion and analysis

9.1 Fund requirement for mercury free transition

There are two scenarios for the mercury free transition of mercury thermometer and mercury sphygmomanometer respectively, and each scenario leads to different economic cost, social cost, and fund requirements (see Table 9-1).

Table 9-1 Fund requirements for mercury free transition of mercury thermometer and sphygmomanometer

Mercury-added products	**Transition scenarios**	**Types of incremental cost**		**Fund requirements (ten thousand dollars)**
Mercury thermometer	Scenario 1: galinstan thermometer	Enterprise's economic cost of phasing out mercury-added products		26299.49
		Social cost of phasing out mercury-added products	Situation I	63651.2
			Situation II	38301.2
	Scenario 2: electronic thermometer	Enterprise's economic cost of phasing out mercury-added products		24645.02
		Social cost of phasing out mercury-added products	Situation I	45276.2
			Situation II	27276.2
Mercury sphygmomanometer	Scenario 1: electronic sphygmomanometer	Enterprise's economic cost of phasing out mercury-added products		4410.05
		Social cost of phasing out mercury-added products	Situation I	35594.32
			Situation II	21460.72
	Scenario 2: aneroid sphygmomanometer	Enterprise's economic cost of phasing out mercury-added products		5974.64
		Social cost of phasing out mercury –added products	Situation I	741.32
			Situation II	548.92

For the scenario 1: transition from mercury thermometer to galinstan thermometer, the fund requirements for the transition of enterprises is about US$ 263 million, and the incremental social cost is at the rage of US$ 400～600 million; for the scenario 2: transition from mercury thermometer to electronic thermometer, the fund requirement for the transition of enterprises is about US$ 246 million, and the incremental social cost is at the rage of US$ 300～500 million. The fund requirements for the transition economic cost of enterprises and social cost for the scenario 1 are higher than that for scenario 2. In view of the current circumstance in China, if galinstan thermometer is chosen as the alternative product, special consideration should be given to the supply of tin ore resource and the price change of metal tin. In recent years, the price of metal tin which is the raw material for making galinstan thermometer has been increasing. China's tin ore reserve and reserve static supply guarantee period are gradually decreasing. All these factors have relatively great impact on the production cost of galinstan thermometer, needing comprehensive consideration in the fund requirements for the transition.

For the scenario 1: transition from mercury sphygmomanometer to electronic sphygmomanometer, the fund requirements for the transition of enterprises is about US$ 40 million, and the incremental social cost is at the rage of US$ 200～400 million; for the scenario 2: transition to aneroid sphygmomanometer, the fund requirements for the transition of enterprises is about US$ 60 million, and the social cost is about US$ 7 million. The fund requirements for the transition economic cost of enterprises for the scenario 1 is lower than that for scenario 2, but the social cost is higher than scenario 2. In terms of enterprise's perspective, the transition to electronic sphygmomanometer is more feasible and more readily accepted by enterprise due to its higher production profit than aneroid sphygmomanometer.

9.2 Problems and challenges in mercury free transition

To achieve the transformation of mercury thermometer and sphygmomanometer producing enterprises and the substitution for mercury-added products, China will face great challenges in the technology, policy, capacity-building, funding needs, and other aspects. In view of China's current economic and technological level it is difficult to complete the transition in a short time.

Technology issue: there is no domestic technology of electronic thermometer and sphygmomanometer chips. All these chips need to be imported from abroad. The cost of independent research and development of chips is higher than the cost of import, thus enterprise lacks enthusiasm and initiatives for the independent research and development. The quality of domestically produced alternative electronic products can not fully meet the requirements of complete substitution due to the relatively low technical level of the enterprises in their production process. The product indexes of domestically made electronic thermometer, such as repeatability and consistency are much worse than the imported products. The domestically made electronic manometer can only meet the general requirements for household and medical institutions. There is no capability to produce the high-precision sphygmomanometer of monitoring type in China, which being used by large medical institutions are imported from abroad. The galinstan thermometer developed domestically also faces the technical issue of improving production process.

Policy issue: The full substitution for mercury thermometer and mercury sphygmomanometer needs the development of relevant national policy, legislation, and standard systems. The establishment of such management systems is targeting on medical device producing enterprises and consumers including hospitals. Therefore, while developing policy for phasing out mercury-added products, the production standard, use and verification standards, quality standard of the alternative products, and other supporting policies are also needed to be developed and implemented in order to meet the special need of hospitals in disease examination.

Capacity building issue: It is necessary to establish a sound verification mechanism for the production and use of alternative products in order to guarantee the quality of alternative products. The production technology of alternative products in China is relatively backward, and China lacks corresponding means and capacity for product testing and verification. To support the promotion and use of alternative products, the state should establish the specialized product testing and verification institutions, develop unified testing and verification method, and train testing and verification technicians and administrative personnel in relevant departments.

Funding issue: To achieve the full substitution for mercury thermometer and mercury sphygmomanometer, it is imperative to put a lot of money into addressing the technology, policy, and capacity building issues mentioned above. In addition, large amount of fund is needed to compensate enterprises in transition and customers. There are 944,000 medical institutions in China, of which 909,000 are grass-root medical institutions, accounting for 96% of the total. Given the relatively high use cost of the alternative products, the large medical institutions have little difficulty in implementing the substitution for mercury products due to their relatively adequate fund guarantee. However, the grass root medical institutions being short of fund could not bear the cost of substitution for mercury products in the short term if there is no financial compensation. This is an economic difficulty facing China in the mercury free transition.

Furthermore, the substantial social cost of substituting mercury free products for mercury-added products has constituted a challenge to user population in terms of their acceptability and use habits. The average people including medical personnel are used to using conventional mercury-added products, especially in hospitals where the mercury sphygmomanometer is commonly used and is of the relatively fixed channel of procurement. To guarantee the sustainability of the mercury free transition, the state should issue corresponding policies, such as compulsory procurement of mercury free products by medical institutions, appropriate subsidy for the price difference, encouraging customers to buy mercury free products, and, at the same time, conduct publicity for and strengthen the promotion of mercury free products, thus making the public gradually accept those mercury free products. The management on mercury free product production and use needs to be improved and strengthened in order to meet the requirements for the transition and substitution for mercury thermometer and sphygmomanometer.

References

[1]. UNEP, Global Mercury Assessment, 2002

[2]. European Commission. Mercury.
http://ec.europa.eu/environment/chemicals/mercury/, 2011

[3]. US EPA, Mercury laws and regulations.
http://www.epa.gov/mercury/regs.htm, 2011.

[4]. Guiding directory for industrial restructuring (2011edition), NDRC

[5]. Report on major mercury-containing products and processes, their substitutes, and experience in switching to mercury-free products and processes.
http://www.chem.unep.ch/mercury/OEWG2/documents/g72)/Chinese/OEWG_2_7Add_1_c.pdf

[6]. Hu Jianxin, et al. China is reducing and phasing our pesticide POPs, Strategy Study

[7]. US CIA, Table of annual discount rate of central banks of each countries
https://www.cia.gov/library/publications/the-world-factbook/rankorder/2207rank.html,2010-01-07

[8]. T.C. Chang, J.H. Yen. On-site mercury-contaminated soils remediation by using thermal desorption technology, Journal of Hazardous Materials, 2006.

[9]. UNEP, draft guideline on the socio-economic assessment of the development and implementation of national implementation plan in accordance with the provision of POPs convention, 2007.