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Analysis of Mercury-Containing Medical Devices Substitution in Healthcare Sectors

Global Village of Beijing

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Editor: Wang Hailong
Translator: Zhu Yan, Wang Weijin, Lv Zhi, Cai Baoxue,
He Yue, Sun Yan, Yin Yadan
Proofreader: Zhang Hong, Jiang Chao, Chelsea Sosnowski, Michael Lu
Layout & Cover Designers: Long Binbin

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Content

Forward

The emission of mercury from the health sector may not be the most important source of global anthropogenic mercury emissions, but it is closely related to human health issues; especially in hospitals where vulnerable patients are relatively concentrated and the demand for instruments containing mercury are very large.

Data collected from the China Medical Device Industry Association shows that mercury consumption in the national production of mercury thermometers and mercury sphygmomanometer in 2008 amounted to 227.05 tons. Therefore, China's health sector has great responsibility in reducing mercury pollution.

Traditional thermometers, blood pressure instruments, esophageal dilators, ultraviolet disinfection lamps, and other medical equipment all contain mercury. Dental amalgams, along with other chemicals that can be found in health sectors are other examples of substances that contain mercury.

If the mercury within these devices spills and is not handled properly, it may cause serious hazards to human health and the environment. For example, a thermometer contains about one gram of mercury, and if this were to leak and evaporate totally, the mercury concentration could be as high as 22.2 mg / cubic meter in a room of 15 square meters and 3-meter height (15x3 sq meters). China's provision of the maximum allowable concentration of mercury indoors is 0.01 mg / cubic meter. Incineration of mercury-containing medical waste also increases the amount of mercury that is emitted into the atmosphere; causing a direct increase in the global mercury load. In addition, the production of these medical devices that contain mercury contributes to the mercury pollution in the environment.

Mercury pollution can spread worldwide as through atmospheric circulation or movement of ocean currents. As a result of its property of causing cross-border pollution, it has been listed as a global pollutant by UNEP. "Mercury emissions reduction and adverse effects elimination of mercury" has become a global consensus. Many countries are actively taking measures to limit mercury, including imposing restrictions to, or even prohibit the use of mercury thermometers and mercury sphygmomanometers.

Using mercury-free medical devices as an alternative to traditional mercury-containing ones is an effective way to reduce the environmental load of mercury. With the development of technology, the possibility of developing an alternative is both technically and economically possible. At present, the mercury-free medical devices are rarely being used to treat patients yet; many hospitals still use the traditional

products that contain mercury in China. Generally, the staffs in these hospitals are uninformed about the movement towards mercury pollution prevention. Besides the economic cost considerations, medical professionals have their doubts on the accuracy of mercury-free alternatives and the disjunction of production goals between the manufactures and needs of professional users. The disjunction between the manufacturers and the professional users is hindering the implementation of the mercury-free instruments into hospitals.

In order to raise community awareness of the mercury pollution hazards this report has been prepared to inspire relevant departments and the general public towards the push of mercury pollution reduction process in mercury-containing medical devices, while also promoting joint efforts of all stakeholders to explore a way to mercury-free medical device in line with China's national conditions.

There will be some errors or omissions inevitably in the preparation, translation and proofreading of the report, we welcome comments from colleagues and readers.

1. Toxicology of mercury

1.1 Mercury species

Naturally, mercury exists in different chemical forms and can be interchanged between different forms. Mercury of various forms which have different toxicity characteristics enters human bodies in distinct ways, and need different measures of treatment and harms prevention.

1.1.1 Elemental mercury

Elemental mercury (mercury Hg) is liquid at room temperature, with a melting point of -38.87 ℃, a boiling point of 356.7 ℃, and a density of 13.59 grams / cubic cent. It can easily evaporate into the air causing harm, and the higher the temperature is , the more rapid the evaporation is; Each additional increase of about 10 ℃ will speed the evaporation rate by 1.2 ~ 1.5 times. The increase of airflow also increases the rate of evaporation. Elemental mercury, which is insoluble in water, can also evaporate into the air through the seal water surface.

Elemental mercury has low viscosity and good mobility and can easily be broken into small mercury beads. These characteristics allow the all-pervasive mercury to enter the gaps of tables, floors, etc., which is difficult to remove and the evaporation process is accelerated due to the additional surface area the mercury covers. Surface of floors, tables, walls, and ceilings can absorb mercury vapor; therefore the hazard of residual mercury remains even after the original source of mercury has been removed. In addition, mercury absorbed in workers' clothes and skin may be brought home and may harm the health of family.

1.1.2 Inorganic mercury

Mercury rarely exists in the form of pure liquid metal. Mercury is more commonly found in the form of inorganic salts or compounds. Inorganic mercury compounds include mercury nitrate (Hg (NO3) 2), mercuric chloride (HgCl2), calomel (HgCl), mercury bromide (HgBr2), arsenic mercury (HgAsO4), mercury sulfide (HgS), mercuric sulphate (HgSO4), mercury oxide (HgO), cyanide, mercury (Hg (CN) 2) and so on.

Inorganic forms of mercury are used for mercury compounds, or as a composition of catalyst, pigment, paint, etc.; Inhalation of mercury compounds, such as oral inhalation or absorption through the skin, can cause mercury poisoning.

1.1.3 Organic mercury

Compounds of mercury and organic groups are called "organic mercury". There are various forms of mercury in nature, such as methyl mercury, dim ethyl mercury, benzene mercury and ethyl mercury; of which methyl

mercury is the most common one.

In nature, some bacteria that assimilates and metabolizes sulphate play an important role in the formation of methyl mercury. The bacteria transform inorganic mercury into methyl mercury through the use of an enzyme.

1.2 **Mercury accumulation and amplification in the biosphere and its effect on the environment**

A very important factor in the impacts of mercury to the environment is its ability to build up in the organisms and within the food chain. Although all forms of mercury can accumulate to some degree, methyl mercury is absorbed and accumulates to a greater extent than other forms.

Bacteria in environment that assimilates and metabolizes sulphate plays an important role in the formation of methyl mercury and its entrance into the food chain. The bacteria transform inorganic mercury into methyl mercury through the use of an enzyme. The methyl mercury bacteria may be the food source of animals higher in the food chain or plankton can rapidly consume the excretion of methyl mercury in the water. These plankton may be the food source for the higher-level organisms in the food chain, which starts the infectious circle all over again. As a result of the food chain, the assimilation of methyl mercury is faster than excretion, and animals towards the top of the food chain will accumulate higher concentrations of methyl mercury.

Methyl mercury in the environment can easily build up to harmful concentrations in fish, and the animals and humans who consume fish as part of their diet. Even in places distant from the source of mercury can become diagnosed with mercury poisoning through mercury pollution. Due to mercury's slow atmospheric deposition rate, mercury biomagnifications will also cause toxic effects on the top consumers in the aquatic food chain. The aquatic food web levels are more than the terrestrial ones, so the aquatic food chain biomagnifications is stronger. Biomagnifications of methyl mercury have a significant impact both on animals and humans. Fish seems to bind with methyl mercury; mercury accumulated in carnivorous fish is almost 100% of methyl mercury. [1]

1.3 Channels of into the body's and the target organs of different mercury species

1.3.1 Elemental mercury

The main path of elemental mercury into the body is through vapor inhalation: 80% of the inhaled mercury vapor is absorbed in lung tissue. The mercury vapor easily passes through blood-brain barrier, and has been proven to be a nerve agent. High concentrations of mercury vapor can cause oral, respiratory tract, and lung tissue damage, with some cases even leading to death caused by respiratory failure.

Accidental swallowing elemental mercury is assimilated very slowly, and it is possible for the mercury to pass through the digestive system without causing damage. Long-term inhalation of elemental mercury vapor can cause tremors, gingivitis, and easy excitability, similar to the symptoms of methyl mercury poisoning.

For the general public, the breaking of mercury-containing thermometers is an important exposure route of elemental mercury vapor. After a mercury-containing thermometer is broken, the liquid metal mercury is scattered on the floor or carpet. One's health is unlikely be threatened if the mercury is properly cleaned. However, if consumers are not aware of how to promptly remove the scattered mercury from the broken thermometer, it will eventually evaporate into the air and be harmful to human and environmental health. If mercury leaks in a family setting, such as if a fluorescent tube or thermometer break, the first thing to do is to evacuate unnecessary personnel and open windows for ventilation, to avoid mercury vapor inhalation. Avoid using a vacuum cleaner to remove spilled mercury or heating the mercury because this will increase the risk of inhalation due to a more rapid evaporation rate.

1.3.2 Inorganic mercury

For most people, diet is the most important inorganic mercury exposure pathway. However, the use of whitening creams and soaps containing mercury, or traditional medicines with inorganic mercury compounds, can also cause inorganic mercury exposure.

Inorganic mercury can cause kidney failure and gastrointestinal damage. Mercury salts are irritating, which can make the lips and tongue blister and can also produce ulcers. Other symptoms caused by high-level mercury exposure include rash, sweating, allergies, muscle twitching, weakness and high blood pressure. Inorganic mercury cannot cross the blood-brain barrier, but can reach the kidneys and cause damage.

1.3.3Organic mercury

In organic mercury compounds, alkyl mercury compounds (especially ethyl mercury and methyl mercury) have similar toxicity, while other organic mercury compounds such as merphene, have toxicity similar to inorganic mercury. Among the alkyl compounds, the most important source of methyl mercury exposure is diet, especially fish and other seafood. Carnivorous fish are at a higher risk of containing methyl mercury. Methyl mercury that is ingested by humans is absorbed by the intestinal tract, and then by other parts of the body, most likely to accumulate in the brain. The accumulations of methyl mercury in the brain can lead to central nervous system poisoning.

Methyl mercury can easily pass through both the blood-brain barrier and the placental barrier. Methyl mercury goes to the fetus through the placenta, and accumulates in fetal brain and other tissue, which cause serious threat to the developing embryo; they are more sensitive to methyl mercury 5 to 10 times than adults. In addition, methyl mercury can be present in infants through breastfeeding.

1.4 Case Analysis of Intoxication Caused by Different Forms of Mercury

1.4.1 Elemental mercury poisoning

Case 1 During the spring festival of 2007, a girl named Sun Li, in Mancheng, Hebei province, had diarrhea and a red rash. Sun Li's mother took it as the common cold at first and went to buy medicine from a clinic in town, but Sun Li's condition never improved. Over time, more symptoms - which were quite strange - appeared. Sun Li couldn't sleep at night due to the pain she felt throughout her body. Her hands became so inflamed that she had to have ice bags on her hands consistently. Suddenly, Sun Li started fainting, which eventually increased to her fainting more than 10 times a day. Her conditions only worsened: without having any previous sight issues, Sun Li became blind until the following February. Despite visiting 5 large hospitals in China, no doctor was able to find the cause of Sun Li's symptoms. In early April, under the questioning by Sun, the director of the department of poisoning and occupational disease in Beijing Chaoyang hospital, Sun Li revealed an important piece of information she had been suppressing. She admitted that during the winter months, she used to play with an object that was slippery, which she used to roll in her hands because it was fun. Sun li also revealed that the liquid in the object could continue to flow after it had been broken down into smaller pieces. After revealing this information to director Sun, he insisted that Sun Li take a urine test. The result of the urine test demonstrated that Sun Li exceeded 100 times the normal mercury level in an average human.

After this astonishing result, all the kids in Sun Li's class took a urine test. From the result of these tests, there were 27 students out of 29 who had touched mercury; 9 of whom had been diagnosed with mercury poisoning. The original source of mercury was a water bottle filled with mercury that a student's father brought home from the warehouse of a post office where he worked. The student brought the mercury to school secretly after he found it in his house. The CDC staff found the water bottle containing the remainder of the mercury in the house of this student. The remaining mercury consisted of 0.5kg in weight, which was enough to fill the water bottle 5cm in height.

Case 2 A middle school student named Wang Chen (alias) in Tongzhou, Beijing was diagnosed with mercury poisoning after having symptoms of a headache and vertigo. Wang Chen said he had drunk a bottle of Sprite before he started feeling sick. His family suspected that there must have been traces of mercury in the bottle of Sprite that Wang Chen drank from. The police of Tongzhou were immediately involved in the case. After a two-month site investigation, the police department didn't find any problem with the Sprite and its packaging, but what they did find sparked a new lead. The police found a broken thermometer and the remaining mercury from the thermometer in the house. During questioning, Wang Chen said he had broken a thermometer while in school, so he bought a new one from a nearby drugstore to replace the one he broke. Unfortunately, he accidentally broke the replacement thermometer while in his house. Curious about the mysterious liquid, Wang Chen tasted the mercury and realized he should not have let his curiosity get the best of him. To try and cover up his mistake, he decided he would tell his parents that the tin packaging from a can of Sprite must have

contained mercury, which is how he became sick. After coming up with this idea, Wang Chen rode to an adjacent shop to purchase a can of Sprite. When he returned home, he poured the remainder of mercury into the Sprite and drank the new concoction. Wang Chen's parents were not aware of the elaborate plan that their son had performed to try and cover up his initial mistake of tasting the mercury. Luckily, Wang Chen was able to expel the mercury toxins from his body and make a full recovery.

Case 3 While working in a hospital, a nurse went to visit a patient to take their temperature. After entering the patient's room, the nurse found a broken thermometer on the floor. She thought that the patient accidently knocked over the thermometer, which caused it to shatter. She quickly opened the window in the patient's room and cleaned up the remains of the thermometer. When these tasks were completed, she went to get another thermometer to take the patient's temperature. 8 hours after the finding the broken thermometer in the patient's room, the families of that patient reported to the nurse that the patient tried to kill himself by swallowing the mercury in the broken thermometer. The patient was immediately sent to have X-rays taken. The result of the X-rays showed that there were several lightened spots in the patient's ileocecal junction (the joint of small intestine and colon, located in right lower quadrant in human's body). Although the doctors did not give the patient any serious treatments, they did ask the patient to drink milk to protect digestive tract and to eat vegetables containing rough fibers to accelerate the emitting of mercury. 4 hours after drinking the milk and eating vegetables, the patient took another set of X-rays. The result of these X-rays showed that there were light spots in the patient's sigmoid colon rectum (located in the left lower quadrant in human's body, epimere of anus). After defecation, the doctor didn't find any mercury in the patient's stool test. A third X-ray showed that the light spots that were present in the previous test, were no longer present. The patient remained under doctor's observation for one week, under which the patient's physical condition remained normal.

All three cases above demonstrate one key principle about mercury: the human body is unable to digest mercury. The student is case 2 showed symptoms of mercury poisoning after directly ingesting mercury. The intake of mercury in this case is most closely related to inhaling mercury through the respiratory tract. The students in case 1 were examples of people who received mercury poisoning through the inhalation of mercury. This case of mercury turned to be more severe due to the time of the year that the incident happened. The students were exposed to mercury during the winter months in Beijing. Due to the colder weather in the winter months, people in northern China, including Beijing, normally keep their windows and doors shut to allow the indoor temperature to remain warm. This warmer temperature indoors was an issue for the students in case 1 because the warmer temperature allowed the mercury to evaporate at a faster rate, allowing the students to inhale a more concentrated amount of mercury in the air. Since the student of Mancheng were exposed to the mercury infested air for a longer duration of time, in comparison with the one-time ingested intake of that of Wang Chen in case 2, the students in Mancheng faced more serious health consequences.

1.4.2 Inorganic mercury poisoning

Case1 Mrs. Pan, at 30 years old, treated herself to a skin whitening treatment at a beauty shop every week. This routine continued for half of a year before she noticed a change in her attitude. Mrs. Pan who used to be

very outgoing and energetic became picky and a real Momus. Simple incidents that were rarely noticed by Mrs. Pan, such as her husband not putting his shoes in the right place, now made her furious. This dramatic change in attitude was so strange that she decided to see a doctor. The doctor recommended that she take a urine test after analyzing her behavior change. The results showed that her mercury level was far beyond capacity, so much so that she needed to hospitalization.

Case2 Mrs. Xu, 40 years old, is also a mercury-poisoning victim from the treatments he received at a beauty shop. Xu had been receiving whitening services for a month. During the same month in which she was receiving these services, she often had trouble sleeping due to nightmares. The correlation between the whitening salon treatment and her nightmares was due to her body's reaction to the mercury in the whitening procedure.

Case3 Mrs. Gu, who is 35 years old, is another example of a person who experienced mercury poisoning from beauty products. Mrs. Gu would purchase whitening products from her local beauty shop. Within two months of using these whitening products, Mrs. Gu experienced prickly feelings in her joints. The mercury in the whitening products was the cause of the feelings that she experienced in her joints.

All of the women in cases 4, 5, and 6 used whitening products they purchased from a beauty shop. These products are most commonly found in beauty shops, but they can also commonly be found in large markets. These beauty products are used in removing discolored spots on the skin. Most of these products are sold in a series, where different products are used in different stages during the spot removal process. There can be as many as 6 different products contained within the series to complete the spot removal. The different products in the series range skin cleaner to whitening day cream, whitening night cream, and a whitening mask. According to "Hygienic Standard for Cosmetics" in our country, mercury level in cosmetics should be below 1mg/kg. In May 2010, the Changchun product quality supervision and inspection along with the court inspected these whitening products and the results were astonishing. The mercury level in a brand of whitening night cream exceeded 30,000 times the standard while another whitening night cream exceeded the standard by 8,000 times. With the extreme levels of mercury found in these whitening products, the symptoms of mercury poisoning can show as early as within the first month of exposure; however it is guaranteed that symptoms will show within 6 months of usage.

The symptoms of mercury poisoning from whitening products can be surprising and strange because they vary from person to person. Symptoms can range from brain and nerve damage to kidney damage. Those patients who suffer from Proteinuria symptoms would go to an urology department for treatment, while those who have neurasthenia, insomnia or dysphoria would go to a neurology department.

1.4.3 Organic mercury poisoning

Case1 In the early years of 1950's, in Minamata Town in Kumamoto County, south of Kyushu Island in Japan, there was an increase in the number of residents who were sick. Some of these patients experienced symptoms of developing a lisp, facial dazing, trembling, and neurological disorders. After multiple attempts of treating

their conditions, their symptoms remained present. Eventually these residents lost their lives to their illnesses. In the town of 40,000 residents, more than 10,000 of them developed some sort of illness. Many people in nearby towns were also victims of this strange disease. In Aug. 1956, after many years of investigations and research, the Medical Institute of Kumamoto National University found that the cause of these illnesses was from mercury poisoning in seafood that the residents frequently ate. Since the outbreak of this disease was at such a high magnitude in Minamata Town, the disease was named after the town: Minamata Disease.

The result of the research of how the seafood became mercury infected is as follows. There was an Acetic acid synthetic factory in Minamata Town where two chemicals were used as catalyst in the production - mercuric chloride and mercury sulfate. Theses catalyst only played the role of accelerating chemical reactions. After the chemical reactions had occurred, the water would be drained with the wastewater into the nearby Minamata Bay. The majority of these chemicals would sink into the mud at the bottom of the bay. While the catalyst mercuric chloride and mercury sulfate are toxic, they are not strong enough to cause severe damage on their own. These toxins turned into severe toxic methyl mercury through with the combination of the bacteria methyl-cobalt ammonia, which existed in the mud of the seabed. The methyl mercury was releasing at the annual rate of 1% causing there to be secondary pollution to the seawater above the mud. The methyl mercury contaminated Fishes and crustaceans that were living in the water. After testing the levels of mercury in the seafood, the result proved that the mercury levels in Minamata Bay were 50 times more then edible allowance. With the residents continuing to eat the mercury-poisoned seafood, they gradually became victims of methyl mercury poisoning. Once methyl mercury enters human body, it dissolves rapidly into the human fat, accumulated mostly in human brain. The methyl mercury would also adhere to nerve cells, reduce RNA in the cells, and crack cells to death. The effect of these actions would result in patients having various neurological symptoms.

2. **Mercury pollution caused by the production and usage of Mercury-containing medical devices**

2.1 Mercury pollution caused by the use of mercury-containing medical devices

Medical devices, such as traditional thermometers, sphygmomanometers, esophageal dilators, UV lights used for sterilization, and other measuring devices used in hospitals and labs all contain mercury. Mercury alloys are also found in other chemicals and tooth fillings used by dentists.

The municipal government of Buenos Aires, Argentina was running 33 hospitals and 38+ clinics before switching to substitutes in 2006. Before the switch in 2006, these hospitals and clinics were purchasing nearly 40,000 new mercury-filled thermometers a year. The majority of these thermometers would break over time which means the whole health sector was discharging an average of 40kg of mercury a year in the local hospital environment and global ecosystem. In result of these thermometers breaking, the health sectors needed

to purchase more thermometers. Given these figures and situations at hand, it can be calculated that as a whole country, the health sector in Argentina was discharging 826kg mercury a year, close to 1mt. [2]

Mercury-containing medical devices are not only dangerous to the hospital environment, but also to people's personal home environment. For example, the Toxicology Centre of Gutierrez hospital, a Children's hospital in Argentina's capital Buenos Aires, would receive, on average, 15 calls a month pertaining to mercury poisoning. The majority of these poisonings were the result of a broken mercury-filled thermometer. [2]

Despite environment pollution caused by damage and leakage of mercury-containing medical devices, burning of mercury medical wastes also emits mercury into the atmosphere. Statistics from the EPA shows that before the US health sector phased out mercury (before 1996), medical waste burning equipment was the No.4 source of mercury in the environment. The amount of mercury found in hospital waste water amounted to 4-5%. Every year, 15mt of mercury was sent to the landfill, which was due solely to the breakage of mercury-containing thermometers. Due to the lack of information and research obtained, it is not possible to properly clean up mercury leaks in most areas of Asia, Africa and Latin America. In these parts of the world, the spilt mercury is either burned, buried with garbage in a landfill, or washed down the drain where it would combine with other waste water. [2]

Due to the lack of research and information available on the quantity of mercury released into atmosphere, as a result of damaged or broken medical supplies in China, we can only use mercury consumption quantities in thermometers and sphygmomanometers to indirectly reflect the mercury leakage in medical devices. Sheet 1 contains the statistics of mercury used for thermometers and sphygmomanometers in 1995 and 2000 and contains a proportional comparison to the quantity used nationwide. The statistics show that there was an increase in the consumption of mercury thermometers and sphygmomanometers over those 5 years. From these statistics, we can conclude that the risk of mercury contamination and leakage increased proportionally with the rise of the use of medical supplies containing mercury. With the increase of mercury being released, there was a great threat made to the public's health. The public's health was further put at risk with the large hospitals continually purchasing more thermometers, containing mercury, to replace those that had broken.

Sheet 1: Statistics of mercury consumption for thermometers and sphygmomanometers in 1995 and 2000 in China
(Data in the table is provided by Thermometer Commission of Chinese Medical Device Association)

	Year	Mercury Consumption /MT	Proportion to Total consumption %
thermometers	1995	40.4	2.66
	2000	100	8.01
sphygmomanometer	1995	15.7	1.05
	2000	60	4.92

2.2 **Mercury pollution caused by the production of mercury-containing medical devices**

The production of thermometers and sphygmomanometer does not only cause serious health and safety issues to the health sector environment, but it also pollutes the local and global environment. The Kodaikanal case, which happened in India, is a good example of the devastating effects in the production of mercury-containing medical devices. In 1983, Cheesborough Ponds moved a manufacturer of mercury thermometer from New York, US to a lake resort at Kodaikanal, in Southern India's Bern Hill. In 1998, Hindustan Lever, a branch company of Unilever, bought this factory and operated it until 2001 when it closed. Data shows that during the operation of this factory the mercury content in the air were far beyond International approved safe limits. It was not surprising when operators who worked at this company reported to have a series of professional health problems due to their close proximity to mercury. These health problems included -but were not limited to- fatigue, headache, nausea, skin problems, respiratory issues, and renal dysfunction. When the factory closed in 2001, the site and surrounding environment, including the local lake, were all seriously contaminated with mercury. Meanwhile, mercury wastes were sold to other industries. Among these sales was a sale to a local waste material distributer of 7.4 tons of mercury waste. Sales such as these only worsened the environmental pollution. In the end, the company was ordered to ship 285 tons of mercury waste back to the initial supplier in the United States. The pollution from the mercury plant in India was so severe that the Indian government established a national policy on the cleaning of harmful materials. Although this policy was established, there was still severely polluted and damaged land where the factory was located. [2]

3. **Development progress and analysis of substituting mercury-containing devices**

3.1 **Progress of global initiative to substitute mercury-containing medical devices**

3.1.1 International trends

Mercury pollution, spread through atmospheric circulation or ocean currents in the global scope, with the attribute of the cross-border pollution, now has been listed as global pollutants by the United Nations Environment Programme (UNEP). To reduce mercury emissions and eliminate the adverse effects of mercury call for global joint effort.

In February 2009, Nairobi, Kenya, during the 25th UNEP Governance Council the environment ministers from different countries reached a consensus: from 2010 to 2013, United Nations Environment Programme (UNEP) will hold the Intergovernmental Negotiating Committee series of meetings for five times, and plans to reach a International Convention on mercury pollution controls until the 27th Environment Forum in 2013.

3.1.2 Other countries

United States Research on mercury pollution has been conducted very early in the United States. February 14, 2005, U.S. President George W. Bush announced the reduction of greenhouse gas emissions by 2010, also

announced a reduction plan of mercury atmospheric emissions to 69%. The following table [3] lists the sales of mercury sphygmomanometers in the United States from 1998 to 2005, from which we can see the situation change of mercury-containing medical devices.

Year	Medical Establishment (Ten thousand dollars)	Household (Ten thousand dollars)	Total (Ten thousand dollars)
1998	1050	470	1520
1999	1000	410	1410
2000	950	330	1280
2002	800	0	800
2005	500	0	500

By the end of 2009, 28 states prohibit or restrict the sale of mercury thermometers in the United States, all large domestic chain pharmacies and about 31,844 retail pharmacies have stopped selling mercury thermometers; [2] a sales ban on mercury sphygmomanometer was carried out throughout 13 states, covering 1 / 3 population of the United States. Yet the legislation of these states is often able to get the support from manufacturers and hospitals.

European Union Reducing the use of mercury-containing thermometers and sphygmomanometers has become a trend in the European Union. The United Kingdom, France, Denmark, the Netherlands and other countries took an early start to restrict the use and production of mercury thermometer; now Sweden, the Netherlands and Denmark have already banned mercury thermometers, sphygmomanometers and various other mercury-containing devices. The entire European Union has banned the use of mercury in a variety of medical supplies, including batteries, electronics devices and electrical equipments etc. In January 2005, European Commission implemented a comprehensive strategy to address mercury issues, with a purpose to protect public health and the environment. policy measures include: prohibiting the marketing and sale of mercury-containing measuring equipment of any kind in Europe; banning the sale of mercury thermometers to healthcare sector; no later than 2011, the EU member states stop exporting mercury-containing products; taking control measures to reduce the volume of mercury use in dental amalgam, ensure proper handling of dental amalgam waste; biological monitoring children, pregnant women and other vulnerable groups, to better protect European citizens from mercury exposure; developing global convention regarding control the use of

mercury and mercury trading, support international action on mercury issues. [2]

Developing Countries Since 2006, some developing countries in Asia, Africa and Latin America made great progress in replacement of mercury-containing medical devices. Many hospitals in these countries have committed to mercury-free healthcare, major cities, local and national governments have also introduced relevant policies one after another.

During the first Southeast Asia Clear Mercury Conference, 2006, Philippines Health Minister Francisco • Duke said in a statement, the Philippine government will issue an executive order to completely eliminate the use of mercury in health care sector. In 2007, the Ministry of Health drafted the order, appeal to the greatest extent possible to substitute mercury containing products.

Since the 1980s, the Cuban government introduced a national policy, to substitute the mercury sphygmomanometer with the alternative aneroid sphygmomanometer imported from China. A researcher of National Hygienics, Epidemiology and Microbiology Association, Dr. Raquel Junco stated that No-liquid thermometer is cheaper than mercury thermometer. Junco also wrote in the article, since 1984, Cuba began to allocate every medical school graduates an aneroid sphygmomanometer. Today, the state paid for every three-year medical students a stethoscope and an aneroid sphygmomanometer. In this country, every family medical clinic is allocated with an aneroid sphygmomanometer. Cuba still purchases mercury-containing equipment for the emergency room and other uses, but the number of aneroid devices is far more than the number of those containing mercury. Now, the Cuban government applies a centralized procurement policy for aneroid sphygmomanometer. In 2006, Cuba purchased 70,000 aneroid sphygmomanometer for adults and 2,700 for pediatric use. In 2007, Cuba plans to buy 100,000 units for adults, 3,500 for pediatric, and purchase only 1020 units of mercury sphygmomanometer. However, thermometer situation is not as optimistic. To date, Cuba has not taken any action to replace the mercury thermometer. Therefore, the country imports 1.2 million units per year, the equivalent of about 1.2 tons of mercury, in which 90% is for public use and the rest 10% directly to the health sector. [2]

3.1.3 The situation in China

Nowadays, due to lack of necessary attention to mercury contamination caused by medical devices, either the hospital or the general public don’t hold the right opinion regarding the treatment of mercury pollution. It is very urgent to popularize the knowledge of mercury pollution and very few hospital possesses a dedicated mercury spill cleanup device. According to the statistic from some national Grade A class Three Hospital, the maintenance frequency of sphygmomanometers is over seven hundred a year, in which a considerable part appears mercury spill, nearly ten kilograms of mercury needs to be refilled yearly. Similar mercury leakage found in thermometer cannot be ignored. We pay limited attention to mercury pollution, nevertheless, the National Development and Reform Commission’s “Guidance list of Industrial Structure Adjustment (2005)" categories mercury-in-glass thermometer project, mercury sphygmomanometer project, silver-mercury

amalgams dental material project as restricted projects (National Development and Reform Commission divides industry into three categories: encouraged, restricted and out of class), showing that China pays gradual attention to mercury pollution in healthcare sector.

In July 2006, Beijing Municipal Health Bureau, State Environmental Protection Administration held a project preparation meeting regarding Sino-US cooperation on the reduction of hospital mercury waste in Beijing . During the meeting, Beijing Jishuitan hospital and Tiantan Hospital were selected as the project's pilot hospitals, and the awarding ceremony was held, which kicked off the project of reducing mercury waste pollution in Beijing health system. Based on adequate investigation and analysis and in line with their own characteristics, the two hospitals took measures to reduce mercury pollution and set role model in national medical system. On June 1, 2011, Changchun Children's Hospital and Global Village of Beijing jointly launched the "Changchun Children's Hospital 'Zero Mercury Campaign' in Changchun, announced the first clear mercury action taken in hospitals of northeast region. Changchun Children's Hospital plans to conduct hospital-wide campaign against mercury pollution, enhance staff awareness of mercury pollution and improve the handling measures of mercury leakage. Meanwhile, to apply safe mercury-free alternatives firstly to the Intensive Care Unit and Children's Health Management Center so as to replace the mercury thermometer and phase out mercury-containing medical devices in the future.

Year 2011 is the beginning of China's "twelfth five-year", in "the twelfth five-year " plan, "Integrated heavy metal pollution control and implementation scheme" is the first approved scheme, coordinated by the Department of Environmental Protection, it is jointly developed by Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Land and Resources, Ministry of Agriculture and Ministry of Health etc. On March 12 2011, at a press conference of Eleventh NPC Meeting News Center, Vice Minister Zhang Lijun said, "Focusing the effort on heavy metal pollution, hazardous chemicals pollution prevention and control, executing full implementation of heavy metal pollution prevention program in "the twelfth five-year" plan approved by the State Council". Thus, it shows that China has attached great importance to heavy metal pollution including mercury pollution and give firm commitment to the pollution control and management.

In late 2004, "Environmental Protection Administration (EPA)" and "Department of Health (DH)" in Taiwan Province also announced to all health care facilities the provisions of no longer providing mercury thermometers to in-patient, which was followed by a complete ban in 2006. According to the estimates by Taiwan EPA, the complete ban of mercury thermometers and sphygmomanometers would lead to a reduction of annual mercury production of 1300 kg in 2006.

3.2 **The replacement of mercury-containing medical devices with mercury-free ones is a technical trend**

When a new patient is admitted into a medical clinic, the medical doctor first needs to check the four basic vital signs of the patient: body temperature, blood pressure, respiration, and pulse. Currently, in order to check two of these four signs, body temperature and blood pressure, thermometer and sphygmomanometer must be used. Both of these medical instruments, which have been used for more than a century, are the most commonly used among doctors and nurses. The following is a brief history on the mercury sphygmomanometer; from which we may begin to understand how to develop a mercury-free sphygmomanometer.

In the early 1700s, a British clergyman connected a 9-foot glass tube to a copper pipe, which was then inserted into an artery in the leg of a horse. The blood pressure of the horse raised the water column in the vertical glass tube to a height of 8.3 feet. This was a groundbreaking event in the measuring of blood pressure and established the physiological basis for the sphygmomanometer.

Later, in 1819, a Frenchman, who was a medical doctor and physicist, invented a method to measure blood pressure with mercury manometer. After this discovery was made, all kinds of blood pressure manometers were invented. While many manometers were invented, it was difficult to apply the new technology to humans because of their intrusive and inconvenient properties. During the following years, many renditions of the manometer took shape, which eventually led to the modern sphygmomanometer. All of these pioneering practices were supported by the developing sciences, such as physics and chemistry, which couldn't have been possible without the Industrial Revolution.

In 1986, after 80 years of development, the real mercury sphygmomanometer -in practical sense- was developed. An Italian scientist invented the first non-intrusive blood pressure instrument. The instrument consisted of three parts: a rubber ball, a rubber bag armband, and a mercury-filled glass tube. The instrument measured blood pressure by wrapping the rubber bag armband around the patient's upper arm, squeezing the rubber ball, and observing the level of mercury in glass tube. Compared with the sphygmomanometer used in today's practices, the only instrument missing was a stethoscope. In 1905, a Russian named Nikolai Korotkoff determined systolic pressure and diastolic pressure by monitoring the patient's heartbeat with a stethoscope. Thus, after developing and perfecting the technology for more than a century, the "golden standard" modern way of measuring blood pressure, with a mercury sphygmomanometer, came into being.

Development of mercury-free sphygmomanometer

The development of evidence-based medicine paved a theoretical path for the emergence of a mercury-free electronic sphygmomanometer. Unlike the mercury sphygmomanometer, the electronic instrument didn't have to start with testing on animals. The development of engineering mathematics provided the new technology with an algorithm basis and the invention of IC made it possible to produce more portable and accurate

electronic sphygmomanometers. Over the past years, with the research on mercury sphygmomanometers, the drawbacks and negative results become increasingly apparent; especially its adverse environmental influence. The evident danger of the mercury sphygmomanometers increases the demand for the modern mercury-free sphygmomanometers. The modern electronic sphygmomanometer is also appealing to modern day health facilities because of its capability to comply with the modern technological advancements. With the increasing spread of technology and the internet, the electronic sphygmomanometer is capable of transmitting and sharing data via the internet. Therefore, the focus has shifted from trying to perfect the original mercury-containing sphygmomanometer to developing the young electronic sphygmomanometer. From the point of view of technological development, the advent of electronic sphygmomanometer is a necessity. The measurement of human body's basic vital data can not stay at the level of the First Industrial Revolution without improvement and the electronic sphygmomanometer has broader development space than mercury-containing sphygmomanometer.

3.3 **The replacement of mercury-containing medical devices with mercury-free ones is a clinical must**

Now people have a different view about blood pressure. In the past, what we've been mainly concerned with is the result of one time or several times of measuring. Now the changing tendency of blood pressure attracts more attention. The following are AHA' s opinions on blood pressure measuring:

First point Of all clinical medicine practice, blood pressure is one of the most important data to acquire; but unfortunately, it is also one of the least accurate.

Second point Trained medical personnel acquires current "golden standard" in blood pressure measuring with mercury sphygmomanometer and the method of Korotkoff sounds. But more and more evidence shows that this method may result in the wrong categorization of a large number of high blood pressure patients. And those with normal blood pressure in clinics but higher pressure in other circumstances will be misdiagnosed as healthy. This is attributed to the following three reasons:：

1. Improper or wrong measuring method, which can be avoided.
2. Fluctuation of blood pressure, which is a nature of blood pressure and inevitable. To decrease the influence of fluctuation of blood pressure on measuring results, the only way is to increase the times of measuring. A couple times of measuring in clinic can only give a vague idea of average blood pressure.
3. When a doctor is present, the examinee tends to have higher blood pressure than usual. To avoid this effect, the measuring should be conducted out of clinic.

In addition to the three reasons proposed by AHA, which may lead to inaccurate blood pressure measuring results, the measuring method itself (Korotkoff sounds) has some unavoidable elements that may cause error. As this article is mainly for non-medical pros to read, the Korotkoff sounds technique will be introduced first. A Russian named Nikolai Korotkoff in 1905 invented this technique. He monitored the changing sound of blood flow with a pair of stethoscopes to determine systolic pressure and diastolic pressure. This exact method

wraps a rubber bag arm band around the upper arm, squeezing the rubber ball to charge with a pressure higher than systolic pressure so that brachial artery will be blocked. Then air will slowly be released and the pulsing will reestablished. Toward the establishment of normal blood flow, different sounds can be detected with a stethoscope. Korotkoff divided the sounds into five phases. Phase l, clear sounds appears, which means an obvious pulse can be felt. The value indicated by mercury sphygmomanometer at this time is the systolic pressure, or what people call the high. Phase 2, the sounds become soft and longer. Phase 3, the sounds become crisp and louder. Phase 4, the sounds become vague and soft. Phase 5, the sounds disappear completely. At this time, what the mercury sphygmomanometer indicates is diastolic pressure, or the low. [4]So this method demands the involvement and coordination of hands, eyes and ears of the operator. Due to the limitations of Korotkoff sounds technique itself, great errors may occur even though the operator may be pretty skillful. The errors are caused by the following three reasons: [5]

1. Low-sampling rate. The stethoscope blood pressure measuring is an interruptive process. The mercury column (static pressure) is observed each time a Korotkoff sound is heard, which can be considered a sampling. The sampling rate is about the heart rate of the examinee, about once per second. While for the operator, it is a complicated and coordinated operation. According to some textbooks, the dropping speed of mercury column during measuring should be 2 - 3 mmHg / s, which is hard to realize or uncomfortable for the examinee even if it is realized. Usually, the blood pressure measuring takes no more than half a minute. Deducting the 10 seconds' time for air releasing, the mercury column takes about 20 seconds to drop from 200 mm to zero, at the speed of 10mm / s. The once per second sampling rate may cause an error of ±10mmH g.
2. Low distinguishability. It is not hard to find that in hospitals the numbers in blood pressure reports are usually the multiple of 5 or even 10. Exact numbers like 153, 67 or 82 are rare. This is because the mercury sphygmomanometer is only marked at multiples of 5. During the dropping of the mercury column, it is hard to just with naked eyes the accurate instantaneous reading. This is called low distinguishability in engineering measuring terms.

3. Subjective factors. The personal features of operators vary substantially. His eyesight, hearing ability, speed of reaction or coordination in movement, can affect the measuring results. It can also be affected by mental factors of the doctor.

Third point The adverse effects of high blood pressure on human body can be forecasted by three kinds of measuring results: average value, day-night variation and short period fluctuation. The acquiring of these three kinds of data requires multiple measurements at different times. It is preferable if blood pressure can be monitored around the clock but mercury sphygmomanometer is not suitable for long time continuous monitoring.

We have drawn two conclusions from the above three perspectives. Firstly, the "golden standard" mercury sphygmomanometer is not as accurate as we have thought. It is not scientific for mercury sphygmomanometer supporters to underestimate electronic sphygmomanometer. Secondly, the blood pressure values for clinical

forecasting take multiple times of measuring and are preferred to be monitored around the clock. For medical science to be more efficient, the automatically programmed electronic sphygmomanometer can draw the blood pressure variation charts but it is difficult for the manual version.

3.4 **The economic feasibility in the mercury-free alternatives**

Nowadays, the biggest obstacle to substitute medical equipment containing mercury is not with the technology but rather the cost. The data we have indicated: the investment for changing all facilities containing mercury might be higher than the budget for purchasing these instruments, but from the points of later maintenance, environmental cost, and supplying damaged equipment, it is much cheaper to use mercury-free devices.

Rivadavia is a public hospital in Buenos Aires in Argentina and they have the alternative strategy in their new baby center. 240 mercury thermometers, used from November 2005 to June 2006, were altered by 21 digital thermometers in the new baby center. As the pediatrician said, they not only prevent 360 gram of mercury every year, but also saved costs by using the digital thermometer as alternatives. The center saved $158 in all, which really helped the doctors persuade the managers to change mercury thermometers for all 350 beds in their hospital. 【6】

At the same time, another hospital in Buenos Aires, Posadas, saved a large sum of money by substituting their thermometers. They bought 3,152 mercuric thermometers for 450 beds in April to June 2006. In 2007, all they needed was to buy 355 mercuric thermometers and 188 digital thermometers saving $3,000. Dr. Maria Ines Lutz, head of the program said，“We choose to use digital thermometers instead of the former ones not only for durable products but also for reminding the staff to realize the importance of our health as well as the equipment”. She also said, “Alternatives for mercury-free thermometer gave them great courage and a wider road to banish other kinds of facilities containing mercury, “It gives us hope”. She said, “Now we can firmly improve the program for substituting sphygmomanometers and other mercury facilities”. 【6】

Federico Gomez is a children hospital in Mexico, having 250 beds. CATTA, the partner of Health Care Without Harm predicted that if all mercuric thermometers would be substituted, they would save at least $10,000, including expenses for digital thermometers and batteries as well as the proposal fee for mercury. 【6】

Sao Luiz, the hospital in St. Paul in Brazil has 116 beds. Medical-care workers found that the expenses for maintenance for digital and non-liquid thermometers and sphygmomanometers were much less than for maintenance for the old mercuric thermometers. In fact, they believed if all sphygmomanometer and wall thermometers are shifted, the cost of maintenance and calibration will counteract the initial investment of $9000 in the next 5 years. After that, it will also save an additional $2000 per year. 【6】

The following are the cost ratio of mercury sphygmomanometers and thermometers and mercury-free ones in USA [7].

	The comparison of cost of blood pressure devices/per five years			
	Containing mercury	Non-liquid blood pressure devices		Digital devices
		Immobilized	Mobilized	Life monitoring devices
Purchasing and training				
Purchasing cost	$129	$152	$264	$1,250-$3,000
Batteries	Inapplicability	Inapplicability		$30
Training	$20	$20		$80
Calibration				
Bio-chemical engineering	$100	$100		$10
(15min/calibration*40/hour)=$10/calibration	Every 6 month	Every 6 month		Every 5 years or damaged
Storage and disposal				
Transportation and disposal	$34 hazardous waste	$0.03 solid waste		$0.017 solid waste
Training for mercury leak and devices	$649	Inappplicability		Inappplicability
Total cost for five years	$932	$272	$384	$1,370-$3,120

	The cost of mercury leak of mercuric blood pressure thermometers	
Tough floor/Find early	The tool for mercury leak	$325
	3 hours for disposal	$45
	Disposal barrels for 5 gallon	$620
	Total	$990
Tough floor/Find late	The tool for mercury leak	$325
	10 hours for disposal	$150
	Discard barrel for 5 gallon	$620
	Total	$1,095
Carpet/Find early	The tool for mercury leak	$325
	10 hours for disposal	$150
	Alter 27 square feet carpet	$48
	Discard roller for 55 gallon	$1,000
	Total	$1,523
Carpet/Find late	The tool for mercury leak	$325
	20 hours for disposal	$300
	Alter 90 square feet carpet	$160
	Discard roller for 55 gallon	$1,000
	Total	$1,785
Average cost for mercury leak	$1,539	

Comparison of the cost of thermometer(5 years lifecycle/35,000 times/20times per day)					
	Containing mercury	Liquid in the column	Digit	Tympan	Single shot
Purchasing and training					
Purchasing cost	$2	$13.75	$180	$296	$3,500
Trocar	Inapplicability	Inapplicability	$1,960	$2,100	Inapplicability
			($28per500)	($30per500)	
Batter($5*5,000)	Inapplicability	Inapplicability	$35	$35	Inapplicability
Training	Inapplicability	Inapplicability	$20	$20	Inapplicability
Calibration					
Bio-chemical engineering (15min/calibration* 40/hour)=$10/calibration	Inapplicability	Inapplicability	$70	Inapplicability	Inapplicability
Storage and disposal					
Transportation and dispo	$45 harzadous waste	<$0.01 solid waste	$0.02solid	$70.02 solid waste	$3.00solid waste
Training for mercury leak and devices	$649	Inapplicability			
Total cost for five year	$695	$13.67	$2.27	$2.51	$3.50

The cost of mercury leak of mercuric thermometers		
Tough floor/Find ear	The tool for mercury leak	$195
	3 hours for disposal	$45
	Disposal barrels for 5 gallon	$620
	Total	$860
Tough floor/Find lat	The tool for mercury leak	$195
	10 hours for disposal	$150
	Discard barrel for 5 gallon	$620
	Total	$965
Carpet/Find early	The tool for mercury leak	$195
	10 hours for disposal	$150
	Alter 27 square feet carpet	$48
	Discard roller for 55 gallon	$1,000
	Total	$1,393
Carpet/Find late	The tool for mercury leak	$195
	20 hours for disposal	$300
	Alter 90 square feet carpet	$160
	Discard roller for 55 gallon	$1,000
	Total	$1,655
Broken times every year=3.4 every 100 beds		
Average cost/leak=$270		

3.5 **Case study of "Mercury-free" medical care**

With the help of the challenges and solutions that hospitals carry out in regards to mercury removal programs, there are three cases below on the basis of the analysis of "Motivation", "Action", and "Result" of mercury removing. Although each hospital is different, those cases would be valuable in predicting the

potential difficulties and in estimating the relative cost.

3.5.1 Case study 1, Beijing Tiantan Hospital[1]

Motivation

International cooperation and government initiative: In July 2006, Beijing Health Bureau and National Environmental Protection Agency convened a pre-preparation conference about the China-US cooperation in reducing clinical mercury waste. At the meeting, two hospitals, Beijing Tiantan Hospital and Beijing Jishuitan Hospital, were elected as pilots. An awarding ceremony subsequently marked the beginning of removing mercury program in Health System in Beijing.

Action

ⅰ. Setting up operation team, regulation and working process of reducing mercury waste

Headed by hospital administrative director, together with other functional departments concerned, Equipment Branch, Nursing Department, Medical Department and Healthy Educational Office rules and regulations were established.

ⅱ. Organizing study and training to enhancing entire staff and patients' understanding of the harm of mercury pollution and requiring 100% realization rate of normal mercury reference by all employees.

Self-design posts of the topic of "Keep away from mercury pollution, rejecting mercury damage" were put up on the obvious wall of hospital. A pamphlet about mercury knowledge was designed and distributed to all staffs. The main contents of the pamphlet contains the general characteristics of mercury harm, pollution way of mercury, clinical manifestation, prevention and first aid of mercury poisoning, mercury poisoning cases, mercury in daily used products and initiative to prevent mercury pollution etc. Moreover, a questionnaire, which included 'how to reduce mercury waste', 'objective of reducing hospital mercury waste' and 'introduction of caution and damage control in equipment and products containing the mercury' were made. Experts were invited to give a lecture on mercury pollution. In this lectures, the speakers introduced the characteristics of mercury and its harm etc.

ⅲ. Controlling the use of mercury containing thermometer and sphygmomanometer

ⅳ. Investing fund on mercury-free products

a. Purchasing electronic sphygmomanometer

b. Conducting clinical comparison and replace sphygmomanometer with electric blood pressure gradually

ⅴ. To exert strict control over non-medical mercury-containing equipments; to designate personnel to take charge of the work; to conduct receiver registration, regularly report of all mercury-containing equipments; to manage the treatments of waster mercury equipment; to replace gradually T5 fluorescent tube with low mercury containing T8 lamp.

Results

[11] Data in the section is from Beijing Tiantan Hospital

ⅰ. The staff's awareness about mercury pollution and protecting skill were enhanced.

ⅱ. Mercury-containing sphygmomanometers were replaced with mercury-free ones and 160 mercury-free sphygmomanometers are in use.

ⅲ. Relative regulations, operating process and documents were produced as the following:

a. Emergency preparatory scheme for mercury spill;
b. Managements method of mercury spill;
c. Management process of collection mercury spill from sphygmomanometer;
d. Management process of collection broken mercury containing thermometer;
e. Reporting of mercury spill from thermometer and sphygmomanometer.

ⅳ. Use of mercury containing sphygmomanometer was reduced.

ⅴ. Management of mercury containing thermometer was enhanced.

ⅵ. Fluorescent tube collection sites were set up.

ⅶ. The goal of reducing 30% mercury waste in the hospital which was set at the beginning of the project has been achieved.

3.5.2 Cast study 2: Beijing Jishuitan hospital[2]

Motivation

International cooperation, government initiative and hospital director's promotion: Beijing Jishuitan Hospital, founded in 1956 is a First-Class general Hospital with accommodation for more than 1000 patients. In 2006, Beijing Jishuitan Hospital participated in the mercury-reducing program mentioned above, which was organized by Beijing Health Bureau, Chinese National Environmental Protection Agency and U.S. Environmental Protection Agency. The director of the hospital was familiar with mercury-free medical devices in developed countries, and was determined and confident to conduct the mercury-free replacement.

Action and Result

ⅰ. Conduct survey on mercury containing products and mercury loss in the hospital

The investigation showed that thermometer was the main reason of mercury loss. Thus, using alternative and setting up a mercury recycling system would be highly effective in reducing mercury loss. (Figure 1)

Due to new material applied in dental filling and the increase of awareness on mercury pollution, use of mercury capsules is decreasing in the hospital. (Figure 2) A clinical survey showed, however, because of incomparable advantages of mercury capsules in regards to price and intensity, the mercury material, which had been used for over 100 years, was still difficult to be replaced completely. On the other hand, we believe that with the continued development of living standards and the advent of new material, mercury material for dental filling will be replaced completely.

[2] Data in the section is from Beijing Jishuitan Hospital.

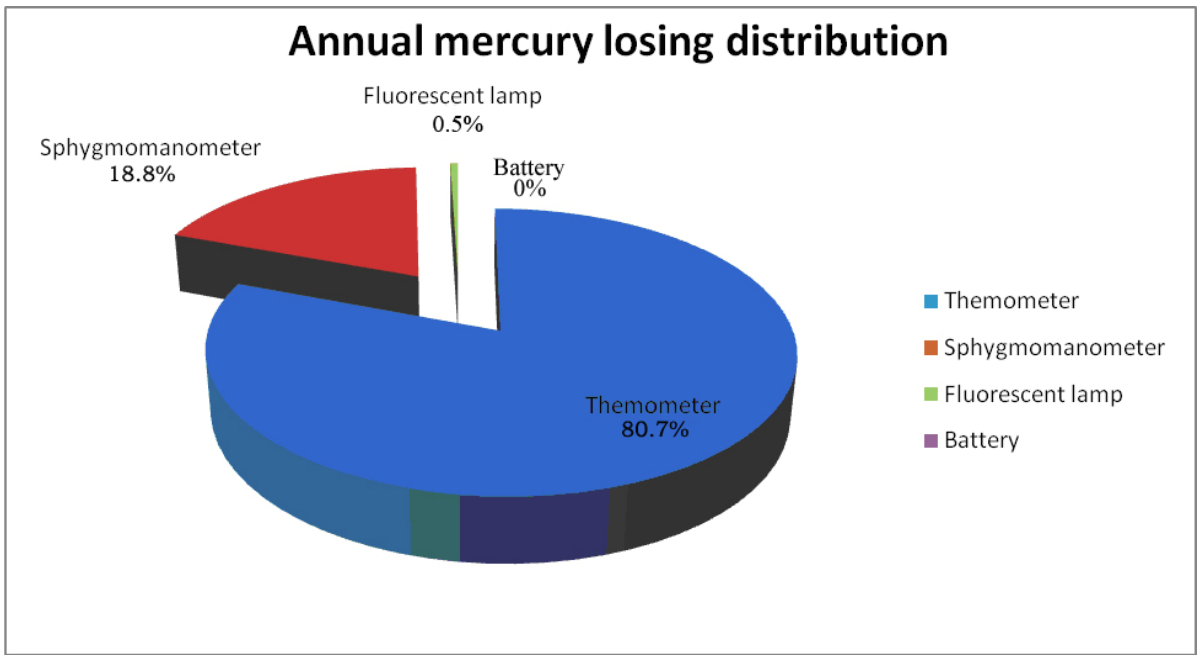

Figure 1. Annual mercury losing distribution

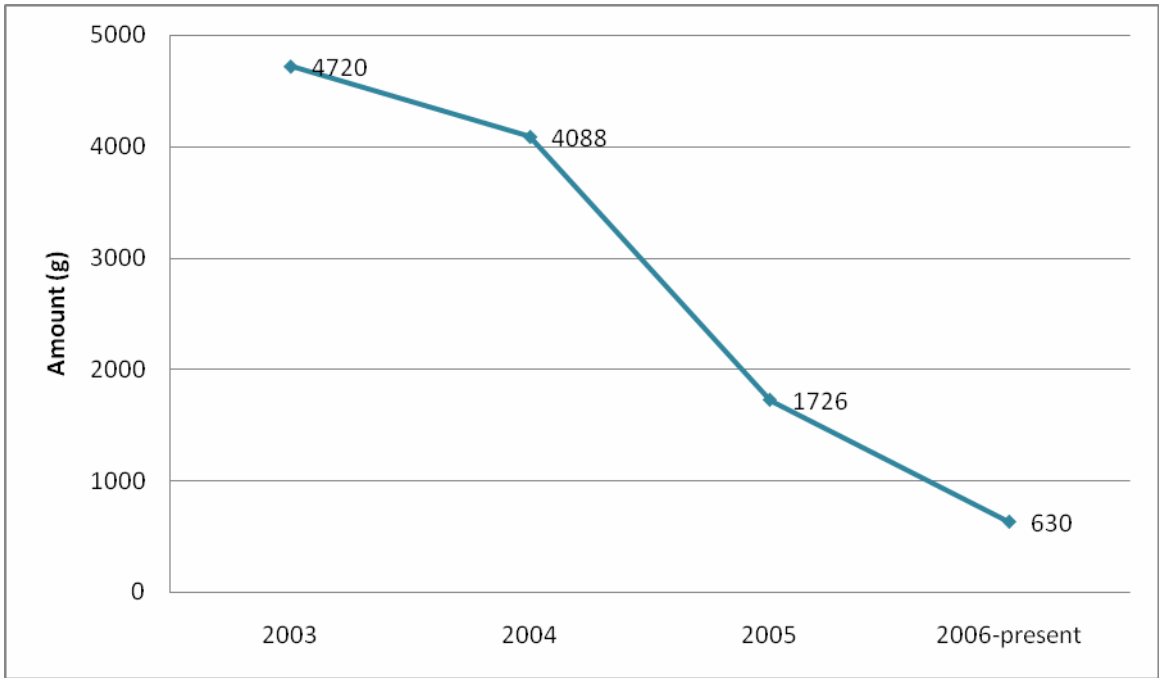

Figure 2. Decrease of mercury capsules used in Beijing Jishuitan Hospital

ii .Conduct education and training on mercury pollution. The staff and patients' awareness and relevant staffs' capability and skill in handling mercury spill were enhanced.

iii.Improve the allocation of sphygmomanometers and reconstruct measuring room to reduce mercury loss during maintenance and adjustment of sphygmomanometer. The effort has reduced mercury emission and at the same time protected technical staff from harm caused by mercury.

iv.Conduct clinical comparison experiments of mercury-free alternatives

a. Preference survey on the alternatives: By visiting 30 clinical sections of the hospital, preference on using mercury-free sphygmomanometer and thermometer to replace mercury-containing sphygmomanometer and thermometer was collected. (Figure 3).

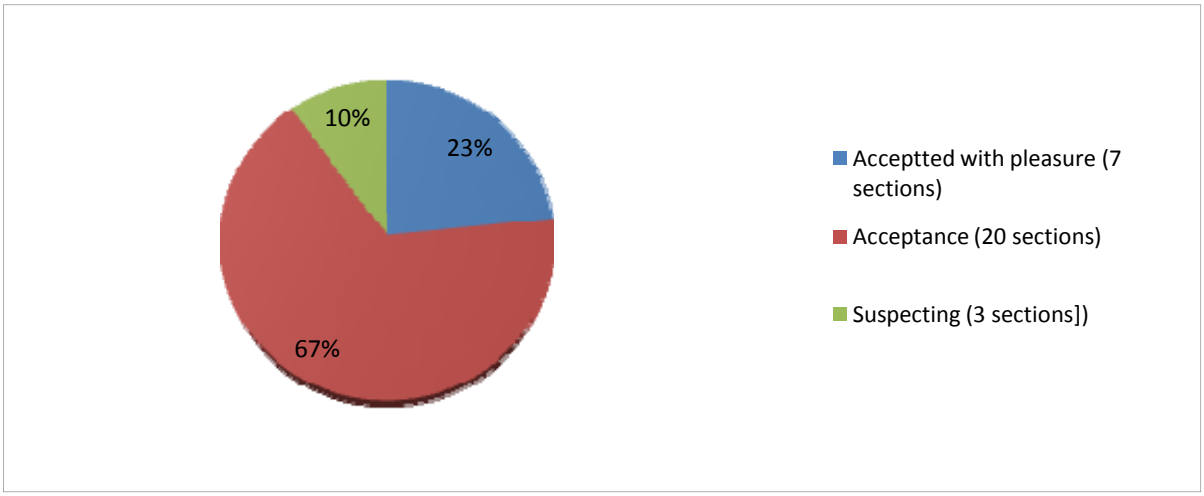

Figure 3. Preference survey

b. Conducting clinical comparison experiments of mercury-containing products and mercury-free alternatives in medical department and special demand ward. The result indicated that there was no significant difference between electronic thermometer and mercury-containing thermometer; when critically ill patients had ultralow blood pressure, electronic sphygmomanometer could not measure it accurately. No significant difference between electronic sphygmomanometer and mercury-containing sphygmomanometer was found in other situation.

v . Substitute mercury-containing thermometers and sphygmomanometers

In August 2009, Beijing Jishuitan Hospital started an extensive replacement of mercury containing thermometer and sphygmomanometer after a one-year experiment and publicity of mercury knowledge. Firstly, mercury-containing thermometers were fully replaced by electronic thermometer and 1350 electronic thermometers were purchased. Before the substitution, the hospital needed to supplement more than 6,000 mercury-containing thermometers each year (about 60% of them caused by breakage). After replacement, no mercury-containing thermometers were supplied. This has effectively reduced mercury loss in the hospital. Until now (April 2011), all the electronic thermometers work well. Only 20 electronic thermometers were supplemented to meet new demands. According to the result got from the comparison experiment and in order to ensure clinical diagnosis work was not affected, the hospital purchased some electronic sphygmomanometers and optimized distribution of electronic and mercury sphygmomanometer. Before the reallocation, there were 172 mercury-containing sphygmomanometers in the hospital and it was reduced to 132

after that. 100 electronic sphygmomanometers were purchased. So far, Beijing Jishuitan Hospital has finished the substitution of thermometers and sphygmomanometers. Only a small number of mercury-containing sphygmomanometers are kept for emergency.

3.5.3 Case study 3: A hospital in Tianjin City

Motivation

The hospital, with accommodation for more than 1000 patients, is a top 3 hospital in Tianjin medical system. There is a special ward in the hospital for foreign patients working in China. These foreign patients who used to mercury-free sphygmomanometer and thermometer required the hospital to use mercury-free medical devices in the ward.

Result

As the patients requested, mercury-containing medical devices in this ward were substituted and the first "mercury-free area" was established in the hospital.

Discussion

Under push of patients' request, the first "mercury-free area" is established in the Tianjin hospital.

4. Proposal

4.1 International Cooperation

With the attribute of long-range transportation and global transmission, the United Nations Environment Program (UNEP) has defined mercury as a global pollutant. Reducing mercury emissions and eliminating the adverse effects of mercury need a joint-effort from the international community. Some developed countries master key manufacturing technology for the mercury-free alternatives. They should, from a technical point of view, help developing countries rather than use this advanced technology to seek further commercial market sharing in those countries, which will suppress or even kill the development of domestic mercury-free alternative technologies and industries, and indirectly support the manufacturing of lag-behind mercury-containing medical devices, and eventually complicate the development process of mercury-free products globally. For the interest of all mankind, it is necessary for the developed countries to provide advanced alternative technologies with low cost to developing countries and developing countries should actively exploit mercury-free alternatives.

4.2 Government's responsibility

In accordance with the actual conditions of China, there are steps and stages to develop mercury alternative policy in line with China's national conditions so as to explore a path towards mercury-free medical care.

ⅰ. Invest funds; draw out policies to encourage the research and development of mercury-free alternative product.

ⅱ. Strengthen the supervision upon major medical device manufacturers with advanced technology and standard management process, urge them to reduce the mercury spill in the process of operation, and improve the recycling of waste product. Meanwhile, sponsor manufacturers with funds and policies, and lead them carry out technological and productive transformation towards mercury-free alternative products. Those "small workshop" producers with outdated technology and chaotic management need to be banned.

ⅲ. Regulate and adopt “Ban the use of mercury gradually, and ultimately eliminate mercury” policy to hospitals and other healthcare establishments. Advocate vigorously the idea of "mercury-free hospital ", "mercury-free clinics" and so on.

ⅳ. Actively promote the knowledge of mercury hazards to the public, raise social awareness level of the danger of mercury so as to motivate individuals to make conscious choices in favor of mercury-free products.

4.3 Manufacturers’ opportunity and challenge

“Zero Mercury” is indeed a huge challenge to those major manufacturers producing mercury-containing medical products. However, as a double-edged sword, it also carries tremendous opportunities. Traditional mercury-containing medical devices are relatively more favored by hospital users. Besides cost, more importantly, the measurement accuracy becomes the main reason. For example, traditional hospital users believe the mercury sphygmomanometer is a more accurate measurement mainly because of the following two reasons.

ⅰ. Product reliability. Most hospitals believe that the alternative lacks accuracy and is poor in repeatability. In this respect, the imported product outperforms the domestic ones. For instance, one imported electronic sphygmomanometers brand accounts for 50% of Chinese market. The local brand’s disadvantage is very obvious in this regard.

ⅱ. Measuring Standard. Hospital users have deep-rooted biases against electronic sphygmomanometer, believing that it is not accurate due to the accuracy measuring criteria.

Currently, there are two incomplete assessment methods towards electronic sphygmomanometer.：

One is only examining the pressure measurement accuracy, which is commonly practiced in some of the manufacturers and technology sector. This one-sided method simply equals the electronic device as an

ordinary pressure gauge, whereas in fact, not only should the equipment be able to measure the pressure in the blood pressure cuff, but also and more importantly (and more difficultly) to judge blood pressure measured through the air pressure when it changes in the cuff.

The other method is to randomly find a few people (and sometimes even a few people with normal blood pressure) as the sampling population, measure their blood pressure with electronic sphygmomanometer, and then test its accuracy against the manual examination results, namely the mercury sphygmomanometers. Hospitals and individual users commonly practice it. However, the mercury sphygmomanometer, which has been considered "golden standard" to judge the accuracy of electronic sphygmomanometer, has been proven to have many problems, which were listed in the previous survey results.

The even more frightening truth is not only that mercury sphygmomanometer is regarded as the “golden standard” to measure the accuracy of electronic sphygmomanometer, but also in modern medicine, after nearly a hundred years of development and accumulation, mercury sphygmomanometer is seen as the “golden standard” to judge a person’s health. Similarly, the facts listed earlier have fully proved that, wherein at a static point, blood pressure value is not able to predict the happening probability of health-damaging diseases. In order to fulfill this goal, a dynamic, continuous curve is needed in order to predict all kinds of healthy risks. Yet, electronic sphygmomanometer that serves this purpose is ignored by doctors, because of the absence of diagnostic criteria bound up with the electronic sphygmomanometer.

It is safe to say that the domestic and foreign manufactures are basically standing on the same starting line in respect to establishing the diagnostic criteria. Information in this area is not as confidential as in e-manufacturing technology, even when the medical development level of some foreign countries is more advanced than us. There are gaps between domestic and foreign manufacturers in producing the alternative products. Domestic companies could switch their focus towards the establishment of the relevant diagnostic criteria, at the end of the day the key to judging the product’s value is to see whether it can accurately predict the risk of hypertension-related events rather than the measuring accuracy it can offer.

Therefore, to meet the challenges, we must change business perspective in terms of developmental ideas and thoughts, so as to discover a new path towards “mercury free” whilst bearing in mind the users (hospitals)’s needs.

4.4 Hospital’s responsibility

Hospitals account for irreplaceable responsibilities in reducing mercury pollution. Strengthening the supervision on using mercury-containing medical equipment and its final disposal is the key to reduce hospital mercury pollution. The specified actions are as following:

First, investigate and identify the quantity and distribution status quo of mercury-containing devices,

establish a mercury-containing devices list, and collect the statistics of the annual usage and turnover of each categorized devices. Possibly, make frequency counts for mercury spills.

Second, based on the statistics result, make plans for mercury-free alternative devices and formulating goals and measures to eliminate mercury pollution.

Finally, regularly assess the progress of reducing mercury pollution, a crucial step is to vigorously popularize the knowledge of mercury pollution among doctors, nurses and technical staffs and promote the proper way to deal with mercury pollution.

Cooperate with alternative manufactures actively, explore and establish the diagnostic criteria associated with the alternative product.

4.5 Individual's participation

Actively study the knowledge concerning mercury hazards and try to avoid using mercury-containing products.

4.6 Non-Governmental Organization's action

ⅰ. Actively popularize environmental mercury hazard knowledge and develop a healthy atmosphere for public opinion on this matter. Raise the level of social awareness and promote the public to take initiatives.

ⅱ. Provide intellectual support for government policy-making and push forward the deployment and implementation of the policy.

ⅲ. Constructively enable the cooperation between manufacturers and hospitals, so as to support the corporations in exploring a new development path.

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About Author

Da Long (Wang Hailong), a medical practitioner, became an environmental protection volunteer of Friend of Green China, Tianjin, a NGO in 2005. He built a close relationship with Global Village of Beijing in 2008 and started to make contributions for “Zero Mercury Campaign”.

Global Village of Beijing (GVB)
Chemical Safety and Environmental Health Program
Address: Room 301, C Building, Huazhan International Apartment, No.12, Yumin Road, Chaoyang District, Beijing, 100029,China
Tel: +86-10-8225 2046 ext.812
Fax: +86-10-8225 2045
Website: www.gvbchina.org.cn
www.chemical.ngo.cn